Postprint of Research on Bounded Rationality Characteristics of Information Search Based on Prospect Theory

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Abstract

[Purpose/Significance] Grounded in the core tenets of prospect theory, this study delves into the bounded rationality characteristics of information search, aiming to uncover decision-making behavioral patterns in users' information search processes, thereby providing theoretical guidance and methodological support for the accurate analysis, evaluation, and prediction of information search user behavior. [Method/Process] Building upon an exposition of prospect theory's core tenets, survey and statistical analysis methods are employed to verify reference dependence, risk preference reversal, loss aversion, diminishing sensitivity, and framing effects in users' information search. [Results/Conclusions] Users' bounded rational behavior in information search aligns with prospect theory characteristics: users exhibit reference dependence in both efficiency and effectiveness dimensions when searching for information, demonstrate risk-averse tendencies when facing gain prospects while showing risk-seeking tendencies when facing loss prospects; the perception of delay is more intense than that of completing tasks ahead of schedule, conforming to loss aversion, and the further from the reference point, the less marginal change the decision-maker perceives, exhibiting diminishing sensitivity; concurrently, the framing effect is pronounced, manifesting as risk avoidance in positive frames and risk seeking in negative frames. This provides experimental evidence for employing prospect theory to explain and predict user information search behavior.

Full Text

Preamble

Bounded Rationality Characteristics of Information Searching Based on Prospect Theory

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Abstract

[**Purpose/Significance**] Based on the core tenets of prospect theory, this study investigates the bounded rationality characteristics of information searching to reveal the decision-making behavior patterns of users during information search processes, providing theoretical guidance and methodological support for the precise analysis, evaluation, and prediction of user information search behavior. [**Method/Process**] Building upon an exposition of prospect theory's core content, this study employs survey and statistical analysis methods to verify reference dependence, risk preference reversal, loss aversion, diminishing sensitivity, and framing effects in user information searching. [**Result/Conclusion**] The findings demonstrate that users' bounded rational behavior in information searching conforms to prospect theory characteristics: users exhibit reference dependence in both efficiency and effectiveness dimensions during information searches, showing risk-averse tendencies when facing gain prospects and risk-seeking tendencies when facing loss prospects. Delayed task completion generates more intense feelings than early completion, consistent with loss aversion characteristics, and decision-makers' perceived marginal changes decrease with distance from the reference point, demonstrating diminishing sensitivity. Additionally, significant framing effects are observed, manifesting as risk avoidance in positive frames and risk seeking in negative frames. This provides experimental evidence for using prospect theory to interpret and predict user information search behavior.

1 Introduction

In the era of big data, information searching is a crucial pathway for users to obtain information, and its search process is essentially a multi-stage decision-making behavior under bounded rationality constraints. Economist H.A. Simon noted that bounded rationality constraints include two aspects: information constraints, where actors cannot master complete information; and cognitive constraints, where actors cannot comprehensively integrate, process, and handle information [1]. In information searching, users face information constraints from being unable to fully grasp massive amounts of information and cognitive constraints from limited ability to process search results, placing information searching under bounded rationality constraints. The bounded rationality characteristics of information searching have become increasingly prominent but have rarely received effective attention and systematic study.

Information searching's bounded rationality characteristics have been preliminarily validated in information search behavior research, but most studies have focused on individual decision-making behaviors in information searching. For

example, Y. Mansourian et al. [2] demonstrated that user information search behavior exhibits bounded rationality characteristics—users' ability to judge information importance affects their search stopping decisions, with bounded rationality being an important theory for explaining user information search behavior. L. Zach [3] and D. Agosto [4] used bounded rationality as a conceptual framework to study information search strategies and mental models, qualitatively examining decision-making behaviors such as stopping rules and retrieval method selection. However, in studies focusing on multi-stage decision-making behavior in information searching, C. Warwick et al. [6] pointed out that prospect theory should be applied to explore bounded rationality in information searching to deeply analyze user behavior patterns. More importantly, mental models lack appropriate mathematical models and tools, making it difficult to effectively explain and predict decision-making behaviors in user information search processes. This necessitates introducing new theories for systematic analysis of user decision-making behaviors in information searching.

Prospect Theory, proposed by D. Kahneman and A. Tversky [7], provides a descriptive empirical model for bounded rational behavior, offering more systematic and profound insights into user decision-making mechanisms and patterns in real-world environments. The theory provides a complete empirical model suitable for systematically analyzing user behavior and has become a frontier theory in bounded rationality research, earning its proponents the 2002 Nobel Prize in Economics. Prospect Theory has been successfully applied to study user decision-making processes under bounded rationality constraints in economic decision-making [8-9], supply chain decisions [10-11], and transportation planning [12-13], demonstrating its superiority for studying bounded rational decision-making problems. However, no research has yet examined whether users' bounded rational behavior in information searching conforms to prospect theory characteristics or whether prospect theory can be used for interpretation and prediction.

This study reveals the bounded rationality characteristics of users during information searching based on prospect theory's core content, explores the applicability of prospect theory to information search behavior, and provides theoretical guidance for the precise analysis, evaluation, and prediction of user information search behavior, thereby promoting research and application development in information users and information searching.

2 Prospect Theory Overview

Prospect Theory proposes a descriptive empirical model of bounded rational behavior, enhancing the explanatory and predictive power of decision-making behavior and providing scientific theoretical support for studying bounded rational decision-making. The theory posits that decision-makers' processes consist of two stages: editing and evaluation. In the editing stage, decision-makers analyze various possible situations, construct decision problems, select appropriate reference points based on their current status and expectations, and encode

the consequences of implementable actions—when exceeding the reference point ($\Delta x \geq 0$), it is considered a gain situation; when below the reference point ($\Delta x < 0$), it is considered a loss situation. Prospect Theory's unique framing effect operates at this stage, influencing individuals' reference point selection and consequently affecting their judgment of gain versus loss situations. In the evaluation stage, decision-makers calculate the value $V(\Delta x)$ of each choice in their minds and use a subjective probability weighting function $\pi(P)$ to weight the value function $V(\Delta x)$ to determine behavior, meaning people choose the option that maximizes $\Sigma\pi(Pi) \times V(\Delta xi)$ [2]. The prospect theory value function curve is shown in Figure 1 [Figure 1: see original paper].

The bounded rationality behavior characteristics in prospect theory are summarized in Table 1 :

Reference Dependence: People's judgment of gains and losses is often determined by reference points; decision-makers focus on changes in gains and losses relative to a reference point rather than final average gains (i.e., expected value).

Risk Preference Reversal: Decision-makers' risk preferences reverse near the reference point: when facing certain gains and uncertain risks, most decision-makers choose certain gains and tend toward risk avoidance; when facing certain losses and uncertain risks, most decision-makers choose uncertain risks and tend toward risk seeking.

Loss Aversion: People exhibit asymmetric sensitivity to losses and gains. When facing equal amounts of gains and losses, decision-makers' aversion to losses is greater than their preference for gains.

Diminishing Sensitivity: As gain or loss amounts increase, the positive or negative utility brought by each unit amount decreases. In other words, marginal changes close to the reference point are greater than those far from it. This is reflected in the value function—the gain portion is concave, the loss portion is convex, and both curves flatten out, with growth rates at the ends being smaller than at the top. The loss function is steeper than the gain function, further verifying loss aversion in decision-making.

Framing Effect: This refers to the phenomenon where changes in description lead to changes in subjects' choice preferences. When subjects face two choices with equal expected value ("risky" vs. "risk-free"), if both are described as gains, it constitutes a positive frame; if both are described as losses, it constitutes a negative frame. Framing effects primarily affect risk preferences—decision-makers tend toward risk avoidance when facing positive frames and risk seeking when facing negative frames.

Some studies have confirmed prospect theory's applicability to bounded rationality information search behavior from various perspectives. For example, D. Maxwell et al. [14] studied optimal stopping strategies for search length in information searching, confirming the bounded rationality of information search

behavior and demonstrating its reference dependence characteristics. W. Toshihiro et al. [15] experimentally verified that information search behavior exhibits prospect theory's risk aversion characteristics. However, no research has yet systematically analyzed the bounded rationality characteristics of information search behavior based on prospect theory to provide a basis for using prospect theory to interpret and predict user information search behavior.

3 Research Design

3.1 Scale Design

Based on prospect theory's bounded rationality behavior characteristics, this study verifies information searching's bounded rationality features from reference dependence, risk aversion in gains, risk seeking in losses, diminishing sensitivity and loss aversion, and framing effects. Since no prior research on prospect theory characteristics exists in the information searching domain, to ensure scale quality, we reviewed recent research on the representation and measurement of bounded rationality in prospect theory and referenced relevant scales used in domestic and international studies [9, 16-20, 22] to develop 18 items across 5 dimensions. Risk aversion items in gain situations (RA1-RA4) and risk seeking items in loss situations (RS1-RS5) were based on literature [9, 16, 17, 18, 22]; sensitivity decrement and loss aversion items for information search decision-making (LARA1.1-LARA1.5) were based on literature [9, 16, 17, 18, 19, 22]; and framing effect items (PF1, NF1) referenced literature [9, 20].

Each question in the scale design includes a decision gain/loss standard (i.e., reference point), allowing each item to verify the impact of reference points in information searching. Since previous research primarily focused on contexts such as travel and sports, all questions were fine-tuned based on original scales to fit information searching scenarios—for example, changing travel time to search time, travel satisfaction to retrieval satisfaction, route selection to retrieval platform selection, and match results to search results—to ensure both measurement accuracy and contextual appropriateness. Except for sensitivity decrement and loss aversion, which used a 9-point Likert scale, all other items used single-choice formats. The scale is shown in Table 2 .

3.2 Data Collection

This study employed questionnaire distribution, targeting junior students majoring in Information Management and Information Systems at Wuhan University's School of Information Management. Forty-five students were randomly selected for the survey, including 18 males (40%) and 27 females (60%), with ages concentrated between 20-22 years.

4 Data Analysis

4.1 Risk Preference Reversal Verification

Risk preference reversal verification consisted of three parts: verifying risk aversion when decision-makers gain in information searching, verifying risk seeking when they experience losses, and verifying differences in decision tendencies between gain and loss situations. Specifically, whether decision-makers show risk-seeking tendencies when facing loss prospects and risk-averse tendencies when facing gain prospects, and whether users' decision tendencies differ significantly across different prospects.

4.1.1 Risk Aversion in Gain Verification Five questions were designed to verify risk aversion characteristics when decision-makers gain in information searching, using time constraints, recall rate, and precision rate. RA1.1 and RA1.2 are a pair of questions under the same RA1 type, using time as the information search perception factor to measure decision-makers' risk attitudes in gain situations. Options A and B have consistent expectations (35 minutes) but different variances—B's variance (225) is larger than A's (25) due to B's larger time span. The time limits are equal to or greater than the options' expectations, meeting or exceeding the reference point expectation. Therefore, RA1 measures risk attitudes in time-gain perception situations.

Survey results show decision-makers clearly prefer option A: for RA1.1, 84.4% (38) chose A while only 15.6% (7) chose B; for RA1.2, 73.3% (33) chose A while only 26.7% (12) chose B, indicating risk aversion when facing clear gains in information search decisions.

RA2 uses recall rate as the perception factor to verify risk attitudes in gain situations. Option A meets and exceeds the reference point (80% recall), while option B represents risk seeking—with a 4% risk of loss. Results show most decision-makers avoid the risky option B and choose A: 82.2% (37) chose A while only 17.8% (8) chose B, demonstrating risk aversion characteristics in gain situations.

RA3 also uses time as the perception factor. Option A exactly meets the time constraint reference value, while option B represents a risk of $30\% \times (65\text{-}30) = 10.5$ minutes. Results show most decision-makers choose to avoid risk (option A) when facing clear gains: 82.2% (37) chose A while only 17.8% (8) chose B.

The questionnaire further examined the role of monetary factors in information searching. In RA4, losses and gains coexist—monetary loss versus precision rate gain. Choosing A loses 50 yuan but obtains a precision rate meeting the reference value, while choosing B costs more money (100 yuan) with greater risk of loss. Results show 86.7% (39) chose option A while only 13.3% (6) chose B, indicating that when precision rate reaches the reference point, users psychologically prioritize precision gains over monetary losses, thus most choose risk aversion.

As shown in Table 3 , whether using efficiency (time) or effectiveness (recall and precision) as perception factors, when facing gains, most decision-makers exhibit risk aversion characteristics by choosing option A and abandoning the riskier option B.

4.1.2 Risk Seeking in Loss Verification Loss-related risk seeking verification questions often appear in pairs with gain-related risk aversion questions. For example, RS1.1/RS1.2 pair with RA1.1/RA1.2, RS2/RS3 pair with RA2, RS4 pairs with RA3, and RS5 pairs with RA4—all share the same stem and option B but differ in option A to distinguish between loss and gain situations faced by decision-makers in information searching.

For RS1.1 and RS1.2, like RA1, options A and B have consistent expectations (35 minutes) but different variances due to different time spans—RS1.1: B's variance is 325 vs. A's 125; RS1.2: B's variance is 250 vs. A's 50—indicating option B is riskier. Since time limits (25 and 30 minutes) are below the options' expectation of 35 minutes, decision-makers are understood to be in a loss state.

Table 2 shows decision-makers clearly prefer option B: for RS1.1 with a 25-minute limit far below expectation, 84.4% chose B while only 15.6% chose A; for RS1.2 with a 30-minute limit closer but still below expectation, 57.7% chose B while 42.2% chose A. In both questions, B is the majority choice, indicating risk-seeking characteristics in information search decision-makers under time constraints.

For RS4, which also uses time as the perception factor, choosing A results in a loss of 25+15-30 = 10 minutes, while choosing B represents a possible loss of 30% × 65 = 19.5 minutes. Therefore, option A represents risk aversion in loss situations while option B represents risk seeking. Results show only 14 decision-makers (31.1%) chose A, while 31 (68.9%) chose B, indicating risk-seeking characteristics when facing losses with time as the perception factor.

RS2 and RS3 use recall rate as the perception factor to measure risk attitudes in loss situations. In both questions, option A is below the information search recall reference point, with RS3's option A deviating more than RS2's, and option B carries risk. RS2's option A loss degree is 80%-70% = 10%, while RS3's is 80%-60% = 20%; both option B's loss risk is 30% × (80%-10%) = 21%, with B's risk level exceeding A's in both questions. Results show B choices account for 82.2% and 91.1% respectively, significantly more than A choices, and as perceived loss degree increases (from 10% in RS2 to 20% in RS3), B choices increase correspondingly (from 82.2% to 91.1%). This indicates that when using recall rate as the perception factor, decision-makers exhibit risk-seeking characteristics in loss situations, with stronger risk preference as losses increase.

While examining time and recall rate as perception factors, the study also combined monetary factors (common in decision-making) with precision rate (commonly used in information searching) in RS5 and RA4 to further explore users'

risk attitudes when facing losses. In RS5, although option A costs only 50 yuan with a 15% precision loss (90%-75%), while option B costs 100 yuan with an expected 18% loss, only 35.6% (16) chose A while 64.4% (29) chose B. This shows that when facing certain precision rate and monetary losses, users choose precision rate risk seeking without much concern for monetary loss—willing to spend more money to pursue greater precision rate risk.

RS5 and RA4 results indicate that monetary factors are not very important in information searching, while precision rate perception plays a crucial role: when precision rate cannot reach the reference point, decision-makers are willing to spend more money and take more risks; when precision rate reaches the reference point, decision-makers prefer to spend less rather than continuously spend to pursue higher precision rates. This verifies risk seeking when perceiving losses and risk aversion when perceiving gains using precision rate as the perception factor, while monetary expenditure has little impact on information search perception.

As shown in Table 4 , when facing losses, decision-makers exhibit risk-seeking characteristics.

4.1.3 Verification of Decision Tendency Differences Between Gain and Loss To further demonstrate that decision-makers have different risk attitudes when facing losses versus gains, paired T-tests were conducted on questions with identical stems but different option A values. Results are shown in Table 5 .

Using time as the perception factor, the difference in decision-makers' choices between losing 10 minutes and just meeting the reference point (RS1.1 vs. RA1.1) is significant ($p = 0.000 < 0.05$); between losing 10 minutes and gaining 5 minutes is significant ($p = 0.000 < 0.05$); between losing 5 minutes and gaining 5 minutes (RA1.2 vs. RS1.2) is significant ($p = 0.009 < 0.05$); and between losing 5 minutes and just meeting the reference point (RA1.2 vs. RS1.1) is significant ($p = 0.000 < 0.05$). Another time-based pair RA3 vs. RS4 also shows significant differences ($p = 0.000 < 0.05$), indicating that when time is the perception factor, decision-makers' choices differ significantly between loss and gain situations.

Using recall rate as the perception factor, both RA2 vs. RS2 and RA2 vs. RS3 pairs show significant differences ($p = 0.000 < 0.05$), indicating that when recall rate is the perception factor, decision-makers' choices differ significantly between loss and gain situations. The same conclusion holds for precision rate as the perception factor, with RA4 vs. RS5 showing $p = 0.000 < 0.05$.

In summary, decision-makers in information searching exhibit risk preference reversal characteristics: they tend toward risk seeking when facing potential loss prospects and risk aversion when facing gain prospects, with significant differences in risk tendencies between gain and loss situations.

4.2 Sensitivity Decrement and Loss Aversion Verification

A 9-point Likert scale was used to verify sensitivity decrement and loss aversion characteristics in information searching, where 9 represents extreme satisfaction and 1 represents extreme dissatisfaction. Respondents were asked to evaluate satisfaction under different time scenarios using time as the information search perception factor to express subjective value feelings. Options appeared in pairs with equal early and delayed completion times relative to the reference point to measure decision-makers' gain/loss perceptions. The decision-makers' subjective value change line graph is shown in Figure 2 [Figure 2: see original paper].

Results show that when completing tasks on time, decision-makers' mean satisfaction is 7.31; when delayed or early by 5 minutes, mean satisfaction values are 5.58 and 7.93 respectively; when delayed or early by 10 minutes, mean satisfaction values are 4.56 and 7.98 respectively. The subjective value loss from a 5-minute delay is 7.31-5.58 = 1.73, while the subjective value gain from a 5-minute early completion is 7.93-7.31 = 0.62, with $1.73 > 0.62$, indicating that a 5-minute delay creates stronger loss feelings than a 5-minute early completion creates gain feelings. The subjective value loss from a 10-minute delay is 7.31-4.56 = 2.75, while the gain from a 10-minute early completion is 7.98-7.31 = 0.67, with $2.75 > 0.67$, indicating that a 10-minute delay creates stronger loss feelings than a 10-minute early completion creates gain feelings.

In Figure 2, the slope of the loss portion is greater than the gain portion, showing that decision-makers experience more intense feelings from delays than from early completions during information search decisions, consistent with loss aversion characteristics. Moreover, when moving away from the reference point, the loss feeling from delaying 5 minutes versus the reference point is 1.73, while the additional loss feeling from delaying 10 minutes versus delaying 5 minutes is 5.58-4.56 = 1.02; the gain feeling from being 5 minutes early versus the reference point is 0.62, while the additional gain feeling from being 10 minutes early versus 5 minutes early is only 0.05. Figure 2 shows that users' subjective feeling curve slopes are not fixed—they decrease with distance from the reference point, verifying decision-makers' sensitivity decrement and loss aversion characteristics in information searching.

These results again prove users' bounded rationality characteristics in information searching—reference dependence, sensitivity decrement, and loss aversion: users' judgment of gains and losses is often determined by search reference points; marginal changes closer to the reference point are greater than those farther away; and the pain from losses greatly exceeds the pleasure from gains. These findings align with prospect theory verification studies in other domains. For example, literature [13] shows that user satisfaction with travel departure times is determined by reference points—satisfaction decreases when exceeding the reference point and increases when before it. Literature [14] empirically demonstrates that optimal stopping strategies for search length in information searching are determined by user-set reference points, with shorter

search lengths bringing greater satisfaction than longer ones. Although these studies differ in domain, their consistent conclusions reveal decision-makers' reference dependence. Notably, literature [21] shows that user satisfaction with travel arrival times is determined by their set reference points, with early arrival satisfaction higher than on-time arrival, which in turn is higher than late arrival, and users' sensitivity to uncertain travel times decreases with distance from the reference point. The finding that people experience being late more intensely than being early aligns with this study's conclusions, both revealing reference dependence, sensitivity decrement, and loss aversion characteristics.

4.3 Framing Effect Verification

Two survey questions were designed to test positive and negative framing effects in information searching: PF1 and NF1. In the positive framing effect PF1, option A directly expresses gains while option B reframes the same fact in risky terms; in the negative framing effect NF1, option A directly expresses losses while option B similarly reframes the same fact in risky terms.

Results show that in positive framing PF1, 68.9% (31) chose A while 31.1% (14) chose B; in negative framing NF1, 75.6% (34) chose the positively framed option B while only 24.4% (11) chose A. This demonstrates that in positive frames where both choices are described as gains, decision-makers tend toward risk avoidance (choosing A), while in negative frames where both are described as losses, decision-makers tend toward risk seeking (choosing B). These results confirm framing effects in information searching.

4.4 Reference Dependence Verification

As mentioned above, all scale designs involve standards for search efficiency or effectiveness (i.e., references), so each item can verify reference dependence in user information searching—where the presence of reference points creates differences in choices across scenarios. For example, RS2/RS3 vs. RA2, RS4 vs. RA3, and RS5 vs. RA4 share the same reference points but different scenarios (different option A values), with decision-makers showing significant choice differences (as shown in Table 5). The five questions LARA1.1-LARA1.5 accurately describe different feelings under different scenarios with the same reference point (as shown in Figure 2). The four questions RA1.1-RA1.4 describe decision differences brought by different reference points under the same scenario (as shown in Table 5), revealing users' reference dependence characteristics—different reference points create different value feelings for information search decision-makers. PF1 and NF1 results show decision changes from two different references for the same problem. In summary, these results well demonstrate decision-makers' reference dependence characteristics in information searching.

Since reference dependence is closely related to other prospect characteristics and serves as a foundational feature, its verification in other domains has been discussed in section 4.2 and will not be repeated here.

5 Conclusion

Based on an exposition of prospect theory's bounded rationality behavior characteristics, this study designed a survey scale to verify reference dependence, risk preference reversal, loss aversion, sensitivity decrement, and framing effects in user information searching. Results show that users exhibit reference dependence when searching for information, are risk-averse when facing gain prospects and risk-seeking when facing loss prospects, experience more intense feelings from delays than from early completions (consistent with loss aversion), show decreasing marginal feelings with distance from the reference point (diminishing sensitivity), and demonstrate obvious framing effects with risk avoidance in positive frames and risk seeking in negative frames. These findings demonstrate prospect theory's applicability to studying bounded rationality in information search behavior, providing theoretical guidance for precise analysis and prediction of information search behavior.

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Author Contributions

Chen Jing: Proposed research questions, designed research framework, drafted manuscript
Wang Yijun: Experimental design and preliminary results analysis
Yang Zhizhuo: Experimental design and preliminary results analysis
Lu Quan: Proposed research ideas, designed paper framework, revised manuscript

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Note: Figure translations are in progress. See original paper for figures.