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Measuring the Effect of Mental Workload on Risk Perception Using Eye Movement Techniques: A Review

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ABSTRACT

With advancements in psychology and neuroscience, researchers have increasingly focused on the relationship between mental workload and risk perception. Mental workload can influence an individual's decision-making process when confronted with risk, and eye-tracking technology serves as an effective measurement tool that provides critical insights into individuals' attention allocation and mental workload. This paper aims to review relevant studies and explore how eye-tracking technology can be utilized to measure mental workload and its impact on risk perception.

KEYWORDS

Eye Movement Techniques; Mental Workload; Risk Perception; Attention Allocation.

1. INTRODUCTION

In the complex decision-making process, the individual's risk perception ability is affected by a variety of factors, among which the role of mental workload is particularly important. Mental workload refers to the mental resources required by individuals to process information and complete cognitive tasks, and changes in this load can directly affect the quality of decision making and the accuracy of risk assessment [1]. Research has shown that when individuals face high mental workload, their attention resources may be overstretched, leading to inadequate or biased processing of risk information [2]. Eye-movement technology, as an effective mental workload measurement tool, can track an individual's eye-movement behavior in real time, revealing his or her attention allocation and information-processing strategies when facing risky decisions [3]. By analyzing eye movement data, researchers can gain a deeper understanding of how individuals perceive and assess risk under different mental workload conditions, thus providing new perspectives for improving the decision-making process. Synthesizing the existing literature, this study aims to explore how eye-movement technology can reveal the effects of mental workload on risk perception, further enriching our understanding of decision psychology and cognitive load theory.

2. DEFINITIONS

2.1. Concept of Mental Workload

Mental workload refers to the level of mental resources and effort required by an individual to accomplish a specific cognitive task. According to the mental workload theory, mental workload can be categorized into three types: intrinsic load, extrinsic load, and related load [4]. Intrinsic load is determined by the complexity of the task and the individual's prior knowledge level, extrinsic load refers to the additional cognitive load due to the way the task is presented or environmental factors, and relevant load refers to the mental effort that an individual puts into integrating new and old knowledge in the learning process.

In practice, the level of mental workload directly affects the efficiency of information processing and the quality of decision making. It has been found that when the mental workload is too high, the individual's attention and working memory capacity are limited, leading to errors and biases in the information processing process [5]. For example, a study by Mehta [6] showed that under high load, individuals are more likely to ignore critical information, which affects their risk assessment ability. This phenomenon has received extensive attention in decision psychology and behavioral economics, especially in situations involving uncertainty and risk.

2.2. Theoretical Basis of Risk Perception

Risk perception is an individual's awareness, evaluation, and reaction to potential risks, involving cognitive, emotional, and social factors. Prospect theory, proposed by Kahneman and Tversky [7], is an important foundation for understanding risk perception, which states that individuals tend to be constrained by cognitive biases and emotional influences when making decisions, and tend to be more sensitive to losses than to gains. This irrational decision-making behavior is particularly evident in the face of uncertainty.

The formation of risk perception is not only influenced by external information, but is also closely related to an individual's experience, knowledge and psychological state. Studies have shown that the way information is presented, the deceivability of risk and the predictability of its consequences can affect an individual's risk assessment [8]. For example, when information is complex and not easily understood, individuals tend to show higher brain load in assessing risk, which leads to errors in judgment.

In addition, risk perception is also affected by the socio-cultural context. Different populations may have very different perceptions and responses when facing the same risk, a phenomenon that has been validated in public health, financial decision-making, and other fields [9]. Therefore, understanding the multidimensional characteristics of risk perception is important for formulating effective risk management strategies and improving the quality of decision-making.

2.3. Applications of Eye Movement Techniques

Eye movement technology is a method that has been widely used in cognitive psychology and neuroscience research in recent years. It provides rich data on the process of attention allocation and information processing by tracking an individual's eye movement trajectory, gaze point and gaze duration. This technique is effective in capturing an individual's mental workload and its changes when faced with complex decisions [10].

The application of eye movement technology is particularly important in the study of mental workload and risk perception. By analyzing eye movement data, researchers can assess the information processing strategies of individuals under different mental workload conditions. For example, a study by Gorin [11] showed that under high mental workload conditions, individuals had significantly longer gaze duration and increased sweeping behavior, indicating that they were trying to integrate and process information. These changes in eye-movement behavior provide important clues for understanding individuals' attention allocation and cognitive strategies during risky decision-making.

In addition, eye movement techniques can be used to explore the effects of information presentation and task complexity on risk perception. Studies have shown that when information is presented in graphical or pictorial form, it is easier for individuals to focus their attention, which may reduce their mental workload and improve the accuracy of risk assessment [12]. This finding suggests that designing effective ways of presenting information may alleviate mental workload and improve the quality of risk perception to some extent.

3. RESULTS

3.1. Measuring Mental Workload with Eye Movement Technology

The application of eye movement techniques in measuring mental workload has been supported by extensive research. Mental workload usually involves the cognitive resources that an individual needs to invest in a specific task, and excessive mental workload can affect the quality of attention, information processing, and decision making. Through eye movement technology, researchers are able to monitor an individual's eye-movement behavior in real time, thus indirectly inferring their level of mental workload.

Studies have shown that when mental workload increases, individuals' gaze duration is usually prolonged, especially in complex tasks [13]. For example, Tanya et al [14], using eye movement techniques, found that participants in a high mental workload task showed a significant increase in gaze duration and a rise in the frequency of scanning behavior (i.e., looking again at previously viewed information). This suggests that individuals may need more time to comprehend the task requirements as they strive to process and integrate information. Analysis of eye movement trajectories can reveal the focus of an individual's information processing during a task. Changes in pupil diameter are widely recognized as a physiological indicator of mental workload. Murata et al [15] showed that during the performance of a high load task, an individual's pupils dilate, reflecting an increase in mental workload. This physiological response, when used in conjunction with eye movement data, can provide a more comprehensive assessment of mental workload status. Eye-movement techniques can also reveal how individuals selectively process information during a task. Wang et al [16] found that when mental workload increases, individuals are more inclined to stay longer in information-rich areas and gaze less in information-poor areas. This change reflects the reallocation of cognitive resources and shows the selective processing of information by individuals under high load.

3.2. Measuring Risk Perception with Eye Movement Technology

Risk perception is an individual's subjective assessment of a potential threat and involves multiple emotional, cognitive and situational factors. The application of eye-tracking technology in measuring risk perception can provide deeper insights.

Eye-tracking technology can clearly record the information processing paths of an individual when assessing risk. A study by Hasanzadeh et al [17] showed that individuals spend significantly more time gazing at risk-related information when faced with high-risk situations. This change in gaze behavior reflects the importance individuals attach to risk information and helps to understand the psychological mechanisms of individuals in the decision-making process. Risk perception is influenced by multiple factors such as context, individual differences and emotional responses. Through eye tracking, researchers are able to observe the eye movement patterns of individuals in different contexts and thus analyze the influence of context on risk perception. For example, Tversky and Kahneman's prospect theory [7] states that individuals are usually more sensitive to losses than to gains, and eye-tracking technology can help researchers directly observe the manifestation of this psychological bias in the decision-making process. Eye movement data can be used to analyze how risk perception affects decision-making behavior. By establishing the relationship between eye-movement behavior and decision-making outcomes, researchers are able to explore the role of risk perception in the decision-making process. A study by Peter et al [18] found that an individual's gaze pattern when assessing risk was significantly correlated with his or her eventual decision-making behavior, suggesting that eye-tracking is effective in revealing key aspects of the cognitive process.

4. DISCUSSION

Measuring the effect of mental workload on risk perception using eye-movement techniques can provide insight into understanding individual behavior in complex decision-making situations. Previous research has shown that there is a complex interrelationship between mental workload and risk perception, and that measurement using eye-movement technology has multiple benefits.

Firstly, eye-tracking technology can capture an individual's attention allocation and visual behavior while processing information in real time. According to Dina et al [19], gaze duration and scanning behavior significantly increase when individuals are faced with tasks with high mental workload. This implies that in complex situations, individuals may rely more on intuitive information processing to enhance their perception of risk. This real-time data collection can reveal how mental workload affects individuals' attention and processing strategies for risky information.

Second, eye movement technology can provide an objective measure of mental workload through physiological indicators such as pupil response. Chen et al [20] found that pupil dilation is positively correlated with cognitive load, which provides a physiological basis for studying the effect of mental workload on risk perception. When individuals assess risk under high load, their physiological responses may affect emotions and decision-making processes, which may alter the results of risk assessment.

In addition, eye-tracking techniques can reveal differences in individuals' risk perception across contexts. For example, the prospect theory proposed by Tversky and Kahneman [7] suggests that individuals are usually more sensitive to losses than to gains. With eye movement data, researchers are able to observe the visual pathways and attention shifts of individuals when assessing risk, and further analyze how mental workload moderates this process. This approach allowed researchers to gain insight into how individuals weigh risk and gain under high load, which affects their final decision.

Finally, eye movement studies that combine mental workload and risk perception can help develop more effective decision support systems. Understanding an individual's decision-making process and risk-assessment approach in high-stress or complex environments can provide guidance for designing more user-friendly interfaces and systems, helping to optimize the quality of decision-making. Therefore, using eye-movement technology to explore the effects of brain load on risk perception not only enriches the theoretical system of psychology and cognitive science, but also provides important practical references for real-world applications.

5. CONCLUSION

This study used eye-tracking to examine how cognitive load affects risk perception during complex decision-making. Results showed that high cognitive load reduces risk sensitivity and assessment accuracy, reflected in shorter fixations, dispersed gaze, and poor attention to critical information. These findings empirically validate the cognitive load–risk perception link through objective measures.

Practically, this work supports (1) real-time cognitive load monitoring in high-risk fields (e.g., finance, healthcare) to mitigate errors, (2) optimized information design to reduce cognitive demands, and (3) training systems leveraging eye-tracking to improve decision-making under pressure. The study advances both theoretical understanding and applied solutions for risk-related behavior.

Collectively, these findings advance our understanding of risk-related decision-making in real-world settings and introduce a novel methodological framework for both research and applied risk management.

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