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A Study on the Cognitive Eye Movement Characteristics of Dancesport Judges

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Abstract

Dance competitions, including Dancesport (international standard dance), involve subjective evaluations, and the competition outcome depends on the referee's (judge's) judgment. Visual information extraction in the judging process is a fundamental psychological component. This study focuses on the decision-making process of Dancesport judges, examining behavioral indicators such as reaction time and accuracy rate, as well as eye movement indicators like saccade distance and eye movement trajectory, across judges of different experience levels. The aim is to conduct a comprehensive study on the cognitive processing involved in Dancesport judging and to analyze and summarize the characteristics of mental processing in judges at various levels.The study investigates eye movement characteristics and judgment cognition in Dancesport judges, involving 45 participants divided into three groups: 15 experts (national/international-level judges with over 5 years of experience), 15 intermediates (national-level judges with over 2 years of experience), and 15 novices (sports dance students with over 2 years of training but no judging experience). Data collection methods included a literature review, expert interviews, and eye movement tracking using a Tobii Pro eye tracker with SPSS 17.0 for statistical analysis. Participants evaluated 22 images under varying task difficulties (time-constrained with auditory interference and relaxed with silent conditions) to assess their judgment accuracy, saccadic distance, fixation patterns, and decision-making efficiency. The study reveals significant performance and visual processing strategies differences among dancesport judges of varying expertise. Expert judges demonstrated faster, more accurate decision-making, efficient visual processing, and precise focus on critical technical points. However, novices exhibited slower responses, lower accuracy, and disorganized gaze patterns, especially under high-pressure conditions. Intermediate judges showed some improvements over novices but lacked the

precision and efficiency of experts, emphasizing the importance of experience and training in developing effective visual strategies and cognitive resilience.
Keywords: Dancesport, Ballroom Dance, Referee, Cognitive Characteristics, Eye Movement

Introduction
Since its introduction to China in the 1980s, Dancesport has developed rapidly, both in scale and speed, drawing worldwide attention in just over 30 years (Dai et al., 2022). It has taken root in China, becoming one of the most popular, widely practiced, and fastest-growing sports, with a large participant base. Today, many elite Chinese Dancesport athletes, positioned at the top of the field, have won multiple awards on the international stage. In May 2004, a Chinese athlete stood on the world champion's podium for the first time—a milestone achievement for Chinese Dancesport (Duan et al., 2024).

The rapid growth of Dancesport has led to an increased demand for skilled judges. Yet, there is a lack of ecologically valid research focusing on the psychological processes of judges in this context (Anderlucci et al., 2021). This study uses images of technical moves as experimental material to explore the image recognition strategies and cognitive characteristics of judges at varying levels of expertise under different cognitive loads. By synthesizing these findings, the research aims to develop effective pathways for developing novice judges into experts, contributing to improved training in Dancesport judging.

Given the significant differences between sports, findings from one sport cannot be wholly applied to others. This study takes Dancesport as a focal point, centering on the specific eye movement characteristics of Dancesport judges' cognitive processing. It follows the cognitive processing path involved in Dancesport judging and selects judges at various experience levels, utilizing an expert-novice paradigm. Through eye-tracking technology and related analytical methods, it examines dynamic attention, visual search features, and other aspects of information processing. The study investigates behavioral and eye movement indicators in decision-making under different cognitive load conditions, aiming to uncover the cognitive processing traits employed by expert Dancesport judges. The findings will provide insights for training novice judges and offer a theoretical basis for further research on cognitive decision-making processes in this field.

This study utilizes advanced eye-tracking technology to investigate the judging efficiency, eye movement characteristics, and decision-making strategies of Dancesport judges at different skill levels under varying cognitive load conditions. It aims to provide new perspectives for exploring cognitive decision-making processes and offer scientific evidence for studying cognitive decision-making advantages in sports psychology, thereby broadening the field to some extent.

Literature Review
Cognitive psychology offers five definitions of cognition: (1) cognition as information processing; (2) cognition as mental symbol manipulation; (3) cognition as problem-solving; (4) cognition as thinking; and (5) cognition as a set of dynamic activities including sensation, perception, memory, imagination, conceptualization, categorization, judgment, reasoning, thought, and language use (Eysenck & Keane, 2020). Definitions (1) and (2) represent a narrow understanding of cognitive psychology, often referred to as "information processing theory,"

equating the human brain to a computer. Definitions (3) and (4) highlight cognition's core aspects as thought and reasoning. Definition (5) represents a broader understanding of cognitive psychology.

In sports competitions, any movement is a bodily response to commands from the brain, meaning that the brain must acquire, store, and retrieve information to make decisions that drive physical actions. Understanding and accurately using the concept of "cognition" is crucial for analyzing the complete process by which athletes collect and process information across various sports scenarios (Eysenck & Keane, 2020).

Eye movement reveals how the brain gathers and filters information. Through this "window to the mind," we can explore many patterns of psychological activity. Since the 1980s, as cognitive psychology has flourished, information processing research has gained increasing attention in sports psychology. In dynamic sports situations, questions like how athletes gather information, what kind of information they collect, and how they filter and make decisions have become focal points of interest for sports psychologists. A notable feature of this research is the use of advanced tools and methods, such as eye-tracking devices. Eye movement analysis helps us understand athletes' real-time visual activities during competition—an insight that other research methods cannot offer (Mitchell et al., 2020). This approach supports timely feedback on athletes' performance and enables coaches to provide targeted guidance (Milley & Ouellette, 2021).

Various patterns of eye movement are closely related to psychological changes. The exploration of how people observe objects has never ceased. As early as the 19th century, there were records of studying psychological activities by observing eye movements. However, it was not until the 20th century that scientific instruments were used to observe and record eye movements systematically. Eye-tracking research has gained popularity in the field of psychology and remains a hot topic of study both domestically and internationally (Berkman, 2024; Liu & Cao, 2024; Zhu & Lv, 2023).

The core issue in eye movement research is how to record eye movements accurately. Over the past century, researchers have been dedicated to this challenge and have made significant achievements. In recent years, the development of high-precision instruments has provided effective tools for experimental research in psychology. The improved instruments have greatly enhanced psychological experiments' objectivity and scientific rigor. Currently, eye movement research is widely applied in fields such as pattern recognition, medicine, market research, driver training, and reading studies (Adhanom et al., 2023; Carr & Grover, 2020; Klaib et al., 2021; Lim et al., 2020).

The human eye, a spherical organ with a diameter of approximately 23 mm, is controlled by three pairs of muscles within the eye socket that enable movement in all directions. These movements are coordinated between both eyes and fall into three main categories: fixation, saccades, and pursuit movements (Goettker & Gegenfurtner, 2021; Mahanama et al., 2022).Fixation refers to the ability of the eyes to maintain a stable position to view an object by projecting its image onto the retina. This process aligns the central fovea with the object to achieve clarity but is not entirely static. Subtle eye movements, such as high-frequency microsaccades, slow drifts, and micro jumps, occur during fixation. These minute movements are crucial for effective visual processing and extracting information.

Saccades serve to shift the point of fixation, bringing the next object of interest into the central fovea for clear observation. These rapid movements, reaching up to 450 degrees per second, allow for swift scanning of the visual field. The amplitude of a saccade ranges from 2 to 20 degrees, facilitating quick selection and focus on stimuli, often without the individual being consciously aware of these directional shifts. Pursuit movements occur when the eyes track a moving object to maintain its focus. This process often involves saccades to ensure the object remains within the field of clear vision, adapting seamlessly to the relative motion between the eye and the object being observed.

An eye tracker is designed to precisely record the eyes' position, dwell time, and movement trajectory during fixation tasks. Researchers utilize this data to explore the psychological processes of subjects engaged in various tasks. Key parameters analyzed include eye movement time, direction, distance, trajectory, pupil size, and blink rate (Coe et al., 2024; Rondora et al., 2022; Seha et al., 2021).Eye Movement Time encompasses fixation time, saccade time, and revisit time. These metrics provide insights into the number of fixations, saccades, and revisits across different positions and times, enabling a detailed analysis of eye movement patterns and the underlying information-processing strategies. Eye Movement Direction and Distance reveal fixation points and transitions between them. When combined with time data, these metrics allow the calculation of eye movement speed, offering a dynamic view of visual exploration processes. Eye Movement Trajector**y** overlays the subject's eye movement data onto the visual scene, creating a fixation path map. This map illustrates eye movement's spatial and temporal characteristics, revealing individual differences in viewing patterns under various conditions and postures. Pupil Size and Blink Rate provide additional insights into attention states. Pupil diameter indicates cognitive load during mental processing, while blink rate reflects attentional breadth and focus under different conditions.

In sports cognitive psychology, eye movement research typically employs the expert-novice paradigm (Filho & Tenenbaum, 2020; Li et al., 2021; Massey et al., 2020; Wu et al., 2024). From basic information processing theories, it examines eye movement characteristics from perspectives such as visual search and selective attention to explore the differences in athletic abilities between experts and novices. The main data indicators include eye movement metrics such as fixation count and eye movement trajectory and behavioral characteristic indicators like reaction speed and accuracy. The trend is to evaluate the combined features of various indicators, integrate and analyze eye movement characteristics with internal decision-making traits, and summarize and refine these insights. This approach helps provide effective training models and strategies for novices and further deepens and broadens research in cognitive psychology.

Through the analysis of eye movement experimental results in sports such as volleyball and tennis, it was found that experts can focus on and scan important information, form more efficient fixation trajectories in a short period, process information rapidly, and make more reasonable on-the-spot decisions (Guo et al., 2024). The literature underscores the significance of cognitive processes and eye movement patterns in decision-making and performance evaluation, particularly in dynamic sports. It highlights the utility of advanced eye-tracking technology in capturing nuanced visual search behaviors and cognitive activities, offering an invaluable tool for distinguishing the expertise levels among individuals. In this context, the following methodological framework is designed to empirically investigate the hypotheses surrounding judgment accuracy, decision-making strategies, and the influence of specialized training among dancesport judges. By leveraging cutting-edge eye movement recording techniques, this study seeks to explore and quantify the visual-cognitive advantages of expert judges, setting the stage for detailed experimental analysis.

Methodology

Sampling

The study focuses on the eye movement characteristics and sports dance judges' judgment cognition processes. The subjects are 45 participantsdivided into three groups: the Expert Group (national and international-level sports dance judges with over 5 years of judging experience and having officiated in more than 20 national-level events); the Intermediate-Level Group (national-level first, second, and third-tier sports dance judges, with over 2 years of judging experience and having officiated in more than 10 provincial-level or higher events); and the Novice Group (sports dance students from a sports university, with over 2 years of sports dance training and no experience in live judging). The participants in all groups have normal visual acuity (including corrected vision), are proficient in basic knowledge of sports dance, and have not participated in similar experiments before.

Data Collection

Each sample was asked to read 22 pictures (2 of which were practice materials). 20 were formal experimental materials, and 10 were randomly read under the two task difficulties.) The experimental dependent variables were the time and accuracy of the subjects to complete picture reading and give the result, as well as the saccadic distance, fixation track, and fixation hotspot during picture reading.

Eye movement data were collected using a Tobii Pro eye tracker with a sampling rate of 30Hz. The stimuli were displayed on a 17-inch CRT computer screen with a refresh rate of 85Hz, and the screen resolution was 1024×768 pixels. The distance between the subject's eyes and the screen was approximately 60 cm. Eye movement data from sports dance judges of different skill levels were collected and analyzed during the experiment.

Before the experiment, participants were provided with an explanation of the experiment's purpose, significance, requirements, procedure, and operation method. They were instructed to approach the image reading task with the mindset of a competition judge and to provide ratings on the quality of the movements. Before the experiment, participants completed a self-designed demographic survey to record information such as gender, age, years of judging experience, and judge level. Participants first performed a practice trial to familiarize themselves with the experimental process. During the experiment, images were presented randomly. There was no time limit for completing the task in the low-load condition. In the high-load condition, participants had 4 seconds per image, with auditory interference present. Participants sat about 60 cm from the screen with their heads fixed, and a 9-point calibration was performed before the experiment began, ensuring accurate calibration.

In the experiment, participants were instructed to observe the images on the computer screen and press the spacebar to record the evaluation time once they completed their judgment. After pressing the key, participants provided a technical score for the image on the screen. If there was a technical error, they were required to specify the exact mistake, and a recorder would note it down. Before each image was presented, a calibration point appeared at the centre of the screen. Participants were required to fixate on the calibration point for at least 2 seconds before the image appeared and the experiment timing began.

Data Analysis
After collecting and arranging the relevant data, data analysis and discussion will be conducted using SPSS 17.0 statistical software. SPSS 17.0 will be used to analyze and process the data.

Results
Time of Picture Recognition

Table 1
Time M (SD) for image recognition by Dancesport judges at different levels

	low load	high load
Novice group	50.00（3.60）	51.33（4.19）
Medium group	47.78（3.52）	48.67（3.12）
Expert group	43.22（2.11）	45.33（1.22）

A two-factor repeated measures analysis of variance (ANOVA) was used to assess the impact of different interference conditions on the image recognition and judgment time of sports dance judges at various levels. The interaction between judge level and interference condition did not significantly affect the completion time, $F(2,16) = 1.699$, $P = 0.214 > 0.05$. The main impact of the interference condition was significant, $F(1,8) = 21.125$, $P = 0.002$, with an effect size of 0.725, indicating that the time taken in the high-load condition was significantly longer than in the low-load condition. The main effect of judge level was also significant, $F(1.274, 10.195) = 46.602$, $P < 0.001$, with an effect size of 0.853. There was a substantial difference between the novice and intermediate groups ($P = 0.001$), with a difference of 2.44 seconds. There was also a significant difference between the intermediate and expert groups ($P = 0.001$), with a difference of 3.94 seconds. The results showed that the novice group took the longest time, followed by the intermediate group, with the expert group taking the shortest time. The load condition influenced the time participants took, with all levels (low, intermediate, and high) showing longer times under the high-load condition than the low-load condition.

The Correctness Evaluation
Table -2
Correct Rate M(SD) of Referees of Dancesport at Different Levels

	low load		high load	
Novice group	69.89（2.20）	69.89（2.20）	67.33（2.06）	67.33（2.06）
Medium group	87.56（1.51）	87.56（1.51）	86.11（2.93）	86.11（2.93）
Expert group	97.78（1.30）	97.78（1.30）	97.00（1.41）	97.00（1.41）

A two-factor repeated measures analysis of variance (ANOVA) was used to assess the impact of different interference conditions on the image recognition accuracy of sports dance judges at various levels. The interaction between judge level and interference condition had a significant effect on recognition accuracy ($F(2,16) = 300.544$, $P < 0.001$). Post-hoc analysis revealed that in the novice group, there was a significant difference between the different interference conditions ($F(1,8) = 9.004$, $P = 0.017$), with an effect size of 0.530. However, in the intermediate group, the difference between interference conditions was insignificant ($F(1,8) = 1.529$, $p = 0.251$). Similarly, in the expert group, the difference was also negligible ($F(1,8) = 1.581$, $p = 0.244$), suggesting that different load conditions only significantly affected the recognition accuracy in the novice group, with lower accuracy in the high-load condition. The expert and intermediate groups demonstrated better resistance to pressure than the novice group, highlighting the importance of on-site practice in training judges.

Eye Movement (Saccade) Distance

Table -3

saccade distance M(SD) judged by referees of different levels of Dancesport

	low load	high load
Novice group	11.74（.32）11.74（.32）	11.70（.39）11.70（.39）
Medium group	11.40（.40）11.40（.40）	11.28（.54）11.28（.54）
Expert group	11.13（.49）11.13（.49）	11.21（.48）11.21（.48）

A two-factor repeated measures ANOVA was conducted to examine the effect of different interference conditions (low load vs. high load) on saccade distance during image recognition for sports dance judges of various levels (novice, intermediate, expert).The interaction between judge level and interference condition had no significant effect on saccade distance ($F(2,16) = 0.046$, $P = 0.754$), indicating that the interference conditions did not influence saccade distance differently across different judge levels.

The main effect of judge level was significant ($F(2,16) = 1.432$, $P = 0.013$), with an effect size of 0.421. Post-hoc tests showed that expert judges had significantly shorter saccade distances than novice judges. At the same time, there was no significant difference between the intermediate and expert groups regarding saccade distance. The interference condition's main effect was insignificant ($F(1,8) = 0.118$, $P = 0.740$), suggesting that the interference conditions did not significantly affect saccade distance across all groups.In conclusion, the higher the judge's level, the smaller the saccade distance, indicating more efficient visual processing in expert judges than novices.

Gaze Trajectory

Figure 1. Sports dance referees know the eye movement gaze trajectory.

Gaze trajectory, which refers to the connection between fixation points, provides insight into the participant's gaze strategy. The analysis revealed distinct differences among the groups. Experts demonstrated clear and deliberate gaze trajectories, focusing on critical areas such as common posture errors, foot technique, hip technique, and partner coordination. Their gaze patterns reflected a targeted approach, indicating high expertise and understanding of technical judgment. In contrast, novices displayed disorganized gaze paths, scanning from head to toe or lacking discernible order. Under high-pressure conditions, their gaze became even more erratic, often fixating on irrelevant elements like faces or clothing that offered no value to technical assessment. Intermediate judges exhibited a gaze strategy that was more structured than that of novices yet not as refined as the experts. While their gaze trajectories showed some clarity and direction, their focus lacked the precision characteristic of expert-level evaluation.

Hot Spots of Eye Movement

Figure 2. Sports dance referees know the hot spots of eye movement.

The analysis of gaze hotspots revealed a clear correlation between the judge's level of expertise and the compactness of their gaze. Judges with higher expertise displayed more focused and precise gazes, characterized by smaller fixation areas. Experts focused primarily on critical technical points, disregarding secondary information during image analysis. This targeted approach allowed them to maintain a sharp focus on essential aspects of evaluation. In contrast, novices exhibited a broader and more dispersed attention area. Their gaze patterns were scattered, often lacking clear hotspots, suggesting difficulty in prioritizing relevant visual information for technical assessment.

Discussion

The study highlights the significant differences in performance and visual processing strategies among Dancesport judges of varying expertise levels under different task conditions. Expert judges exhibited faster and more accurate decision-making than their intermediate and novice counterparts, demonstrating greater efficiency under low- and high-load conditions. Their shorter saccade distances and compact gaze hotspots reflected highly efficient visual processing, allowing them to focus on critical technical points like posture errors, foot and hip techniques, and partner coordination while disregarding irrelevant information. In contrast, novice judges took the longest time, had the lowest accuracy, and displayed disorganized gaze patterns, often scanning irrelevant areas such as faces or clothing, particularly under high-pressure conditions. Intermediate judges showed partial improvements, with structured gaze strategies and better accuracy than novices, but lacked the precision and efficiency characteristic of experts. These findings underscore the role of experience and training in developing efficient visual strategies and resilience to cognitive pressure, which is essential for accurate and timely technical judgment in Dancesport.

The findings of this study can be discussed within the framework of cognitive psychology and eye movement research, particularly through the lens of information processing theory and visual search strategies (Guo et al., 2024). The study demonstrates how expertise in Dancesport judging correlates with more efficient cognitive and visual processing, as evidenced by faster decision-making, higher accuracy, and focused eye movements among expert judges compared to novices. These findings align with the broader definition of cognition as a dynamic activity involving sensation, perception, memory, and judgment (definition 5).

Experts' ability to process critical visual information more efficiently can be explained by their advanced visual search strategies and selective attention, key aspects of information processing theory (definitions 1 and 2). Their compact gaze hotspots and deliberate trajectories reflect a refined ability to prioritize relevant technical elements, such as posture and coordination while ignoring irrelevant stimuli. Experts have internalized complex mental models through experience, enabling rapid categorization and retrieval of information during judgment tasks (Kosel et al., 2021).

From a problem-solving perspective (definition 3), experts demonstrate superior skill in identifying and analyzing key performance aspects under low- and high-load conditions, showing resilience to cognitive pressure (Purcell et al., 2021). Conversely, Novices exhibit disorganized gaze patterns and slower reaction times, indicative of less developed problem-solving frameworks and difficulty filtering irrelevant information. The intermediate group's partial improvement underscores the role of progressive skill development in enhancing cognitive efficiency.

The study also supports the utility of eye movement research in sports cognitive psychology. Metrics like fixation time, saccade distance, and gaze trajectory provide insights into how judges' brains gather and process visual stimuli (Kümmerer & Bethge, 2023). Shorter saccade distances and longer fixations among experts highlight their ability to concentrate on critical areas, consistent with the concept of cognition as mental symbol manipulation (definition 2). The application of eye-tracking methods reflects the increasing sophistication of cognitive psychology tools, enabling a deeper understanding of decision-making processes in dynamic sports scenarios.

These findings emphasize the need for targeted training models to develop novices' visual processing strategies, such as guided practice focusing on key technical points and simulating high-pressure conditions. The expert-novice paradigm in this study illustrates how cognitive and visual processing evolves with experience (Lieberei et al., 2023), contributing to the growing body of knowledge in sports psychology and offering practical implications for improving judgment accuracy in Dancesport and other performance-based disciplines.

Conclusions

The evaluation efficiency of sports dance referees increases with their experience level, as higher-level referees demonstrate greater psychological resilience and a more focused, compact gaze during judgment. High-level judges concentrate on key technical points, such as footwork, hip technique, partner coordination, and body posture, while filtering out secondary information. In contrast, novice referees exhibit scattered and irregular attention, covering a broader area but lacking focus. To address these gaps, creating more opportunities for simulation practice and live judging for mid-level and low-level referees is recommended, helping them improve their judging efficiency and psychological resilience. Additionally, efforts should strengthen their specialized knowledge of sports dance technical movements, encouraging the adoption of correct judging strategies and reinforcing them through continuous testing and practice.

The practical implications of these findings for the general dance community are significant, particularly for improving the quality and fairness of dance competitions and fostering the growth of dance as both an art and sport. First, by understanding that higher-level judges focus on key technical aspects and exhibit better psychological resilience, the dance community can prioritize advanced training programs for referees to ensure that competitions are evaluated more efficiently and consistently, enhancing credibility and trust among dancers, coaches, and audiences. Second, the recognition that novice judges struggle with scattered focus highlights the need for targeted educational initiatives, such as simulation exercises and mentorship from experienced judges. These efforts can help develop sharper observational skills and decision-making abilities, essential for accurately assessing dancers' performances.

Furthermore, the emphasis on gaze patterns and focused attention underlines the importance of refining judging strategies as a skill. The community can build a larger pool of competent referees by implementing more opportunities for practical judging experiences and reinforcing knowledge of technical dance movements. This strategy elevates competition standards and promotes fair evaluation, encouraging dancers to invest more in improving their techniques. Finally, these findings can inspire dancers and coaches to better align their training with key judging criteria, such as footwork, posture, and partner coordination. This alignment fosters a deeper understanding of performance expectations and drives overall technical excellence within the dance community.

The theoretical contribution of the study is the incorporation of elements from expert-novice paradigm into information processing theory. We argue that experts' superior ability to process critical visual information more efficiently can be attributed to their advanced visual search strategies and selective attention, which are fundamental elements of information processing theory. The contextual contribution of this study is advancing the understanding of cognitive and visual processing strategies among Dancesport judges, offering significant insights into sports psychology and practical implications for Dancesport training and judging.

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