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Exploring gender differences in visio-spatial intelligence and gaze behaviour: A review of existing research

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Background: Previous research has explored gender differences in visuo-spatial intelligence and gaze behaviour; however, no comprehensive review has synthesised findings across parameters or examined their underlying causes.

Aim: This review critically evaluates literature on gender differences in gaze behaviour and visuo-spatial intelligence. It integrates findings from visual software (cognitive and perceptual processes) and visual hardware (biological and physiological capacities), identifies methodological inconsistencies, and examines sociocultural moderators influencing performance. A dual-framework approach is proposed to explain the interaction between these domains.

Method: Electronic searches were carried out across multiple databases, including Current Contents, ScienceDirect, EBM Reviews, CISTI Source (1990–February 2025), Google Scholar, SportDiscus (1990–February 2025), PubMed (1990–February 2025), the Cochrane Database of Systematic Reviews, and various international e-catalogues.

Results: Seventy-seven full-text articles were reviewed. Consistent gender differences were observed in both biological capacities and cognitive strategies, although methodological variations contributed to inconsistencies. Sociocultural factors such as play experience and training exposure were identified as influential moderators.

Conclusion: Gender differences in visio-spatial skills reflect biological, cognitive and social influences. An interactionist framework is recommended for future research.

Contribution: This review advances understanding by introducing the distinction between 'visual hardware' and 'visual software', critically evaluating eye-tracking research and proposing a more nuanced interactionist framework for future investigations.

Keywords: visio-spatial intelligence; gaze behaviour; vision; visual skills; gender differences.

Introduction

Vision is a multifaceted cognitive process that involves not only the perception of images, but also their interpretation and comprehension. While sight refers to the sharpness of an image projected onto the retina,[1] vision encompasses higher-order cognitive processes, including visual efficiency, spatial awareness and the functional integrity of visual pathways.[2] Among the human sensory modalities, vision is unique in its ability to provide information about distant environmental elements, allowing individuals to anticipate and adapt their movements accordingly.[3] This predictive capability enables individuals to modify their gait patterns to avoid obstacles and achieve specific environmental goals.

Visio-spatial intelligence refers to the capacity to receive, comprehend and manipulate visual and spatial information. It requires abilities such as pattern recognition, environmental navigation and mental rotation of objects.[4] A common misconception is that visual dominance is solely determined by good eyesight; however, this is inaccurate.[5] Successful visual task performance requires more than visual acuity; it necessitates the ability to track and process multiple moving objects simultaneously. The dynamic nature of visual environments demands continuous attentional and perceptual adjustments.[5] Effective situational awareness relies on the integration of visual stimuli with cognitive processes such as working memory, attention and spatial reasoning to interpret and respond to these dynamic changes accurately.[6]

Research has consistently demonstrated cognitive differences between men and women, with these disparities persisting into adulthood.[7] While women generally exhibit stronger verbal

abilities, including language comprehension and usage, men tend to outperform women in visio-spatial tasks, which involve mentally manipulating objects and navigating spatial environments.[8,9] Studies on visio-spatial ability indicate that men perform better in spatial reasoning tasks such as geographic orientation and navigation.[10,11] For instance, men are more adept at navigating unfamiliar environments using landmarks and spatial cues.[11]

Evidence suggests that these cognitive differences become more pronounced during adolescence, highlighting the influence of both biological and environmental factors on cognitive development.[12] Environmental factors, particularly early play experiences, have been linked to improved cognitive performance. Men, for example, often engage with construction toys that require object manipulation and transformation, which has been associated with enhanced spatial visualisation skills.[13] These early developmental experiences may contribute to long-term cognitive outcomes, underscoring the need to consider both biological and environmental influences when examining gender differences in visio-spatial intelligence.[13]

Gaze behaviour refers to the patterns and movements of a person's eyes when observing objects, scenes or people. It encompasses various aspects of visual attention, including where individuals direct their gaze, the duration of their focus on specific areas and the transitions of their eyes between different points.[14,15] While gaze perception generally triggers a strong and automatic shift in spatial attention, there are noticeable individual differences in the extent of this response.[16] Kulms et al.[17] found that women engage in more eye contact than men and tend to look at their conversational partners more frequently when speaking and listening. Similarly, a study by Bayliss et al.[18] revealed that women exhibit a stronger gaze-cueing effect than men. However, regardless of gender, individuals who consider themselves socially skilled tend to experience a pronounced gaze-cueing effect.

This review seeks to determine the degree of gender disparities in visio-spatial intelligence[19] by analysing the developmental, social, biological and cognitive–perceptual elements that affect visio-spatial abilities. Although gender differences in various aspects of visio-spatial intelligence and gaze behaviour have been studied in the past,[7,12] no thorough review has systematically compiled these findings across visual software (cognitive and perceptual processing strategies) and visual hardware (biological and physiological capacities) or examined how these domains interact. Because of methodological differences, a lack of integration of biological and sociocultural moderators and a lack of focus on task-specific contextual factors, existing evidence is even less consistent. To fill in these gaps, this review synthesises previous and current research and suggests a refined dual-framework approach that makes a distinction between visual software and visual hardware to provide a more coherent and clear understanding of gender differences in gaze behaviour and visio-spatial intelligence.

Research methods and design

Literature search strategy

A comprehensive literature review was conducted to examine gender differences in visio-spatial intelligence and gaze behaviour. Electronic searches were performed across multiple databases, including Current Contents, ScienceDirect, EBM Reviews, CISTI Source (1990–2025), Google Scholar, SportDiscus (1990–2025), PubMed (1990–2025), Cochrane Database of Systematic Reviews and various international e-catalogues.

The search strategy involved keyword combinations using Medical Subject Headings (MeSH), including 'gender differences', 'vision', 'males', 'females', 'depth perception', 'eye coordination', 'gaze behaviour', 'visual skills', 'accommodation facility', 'fixation skill', 'saccadic eye movements', 'visual perception', 'reaction time', 'peripheral awareness', 'visual memory' and 'concentration'. These terms were refined and systematically merged for the final search. Only peer-reviewed articles published in English were included. Relevant original studies were identified, categorised and selected for further analysis.

An overview of the article selection process is illustrated in Figure 1.

Inclusion criteria

Studies were included in this review if they met a defined set of inclusion criteria designed to ensure both scientific rigour and contextual relevance. Eligible studies involved participants across all age groups, including children, adolescents, adults and older adults, and included both male and female subjects. Research encompassing both clinical and non-clinical populations was considered, provided that the study investigated the impact of sex or gender on visio-spatial intelligence, gaze behaviour or related cognitive functions. In addition, studies were required to address biological, social, educational or cultural factors that may influence visio-spatial intelligence and gaze behaviour. Only studies written in English or accompanied by accessible full-text translations were considered. To ensure quality and reliability, included studies had to be published in peer-reviewed journals, academic conference proceedings or other credible scholarly sources. Finally, publications from the past 10 to 15 years were prioritised to maintain contemporary relevance, although seminal or foundational works were also included where appropriate to provide historical context.

Exclusion criteria

Studies were excluded from this review if they failed to meet specific relevance and quality criteria. Specifically, studies were omitted if they did not explicitly focus on gender differences in visio-spatial intelligence and gaze behaviour, or if they examined general intelligence without a direct emphasis on visio-spatial skills. Research that addressed visio-spatial abilities and gaze behaviour in contexts

unrelated to cognitive intelligence, such as purely motor tasks or spatial activities lacking cognitive assessment, was also excluded. Studies investigating neurological or clinical disorders were not considered unless they directly examined gender differences in visio-spatial intelligence and gaze behaviour. In addition, studies conducted solely on non-human subjects were excluded, as were unpublished works, including dissertations, conference abstracts lacking full papers, opinion pieces and editorials. Finally, studies written in languages other than English without a reliable translation were not included in the review.

Data extraction

Studies that did not meet the inclusion criteria were excluded from the final analysis. The first author systematically collected and reviewed all relevant data, ensuring a thorough assessment of key findings related to gender differences in visio-spatial intelligence and gaze behaviour. Each study's eligibility was evaluated for full-text analysis. To enhance accuracy and reliability, one of the co-authors reviewed and approved the selected studies. Any discrepancies identified during this process were resolved through discussion and revision to ensure clarity and precision in the final dataset.

Results

This study initially identified 120 citations through electronic searches and selected 87 full-text English-language papers for review. After eliminating duplicates and assessing the full-text articles, 77 full-text remained for analysis. Several studies were identified that examined differences in visio-spatial intelligence, with some reporting variations, while others found no differences. Table 1 presents a list of visual software skills with gender differences, while Table 2 outlines all visual hardware skills with gender differences, including descriptions of each visual skill. Table 3 provides an overview of visual skills related to gaze behaviour and gender differences.

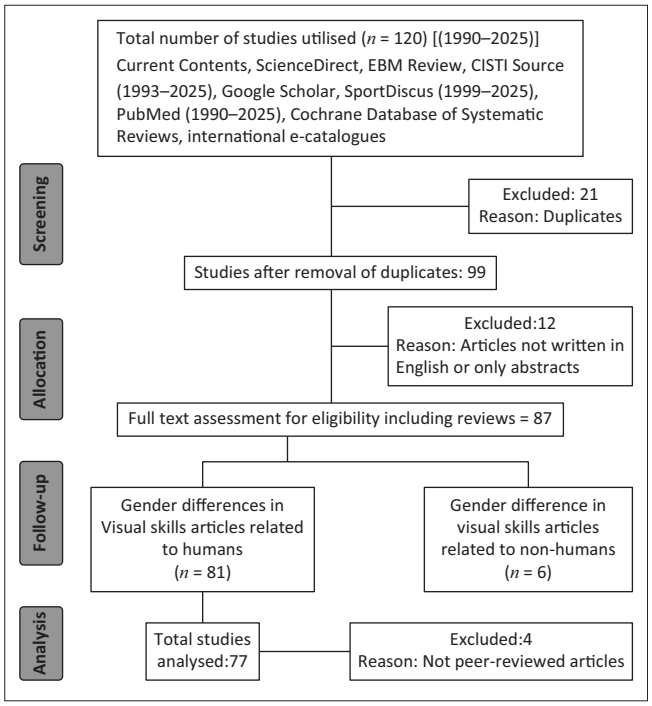

FIGURE 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of the study selection process.

Discussion

Extensive research has examined gender variations in visio-spatial intelligence and gaze behaviour, offering insight into potential differences between men and women in spatial reasoning, visual processing and attention.[12] The suggested dual-framework approach, which differentiates between visual software (cognitive and perceptual methods) and visual hardware (biological and physiological visual capacities), is used in this review to understand the results. This approach makes it easier to understand how sociocultural experiences, cognitive processing inclinations and biological predispositions interact to create the gendered patterns seen in many studies.

TABLE 1: Gender differences in visio-spatial intelligence: Visual software skills.

Visual skill	Description	References
Speed of recognition	Speed of recognition refers to the capacity to swiftly and precisely identify and understand visual stimuli, which is essential for activities such as reading, driving, sports and complicated decision-making.	4,7,19,23,24,25
Peripheral awareness	Peripheral awareness is the capacity of an individual to remain focused on a major job while simultaneously being cognisant of and making use of information from their peripheral vision, without having to look away from the primary focal point.	26,27,28,29,30
Eye–hand coordination	Eye–hand coordination is a perceptual-motor skill that allows for precise motor actions by integrating and interpreting touch and visual information inside the central nervous system.	31,32,33,34,35
Visual memory	Visual memory is the capacity to quickly process and retain intricate mental representations of people and objects in motion.	12,36,37,38,39
Concentration	Visual concentration is the capacity to minimise distractions and concentrate on visual tasks or stimuli.	37,40,41,42,43
Visual reaction time	Visual reaction time is the interval between the presentation of a stimulus and the onset of an appropriate voluntary response.	19,44,45,46,47,48,49

Note: Please see the full reference list of the article, Mathe N, Millard L, Breukelman GJ, Exploring gender differences in visio-spatial intelligence and gaze behaviour: A review of existing research. Afr Vision Eye Health. 2026;85(1), a1098. https://doi.org/10.4102/aveh.v85i1.1098, for more information.

TABLE 2: Gender differences in visio-spatial intelligence: Visual hardware skills.

Visual skill	Description	References
Accommodation facility	To sustain a clear vision over varying distances, the visual system's concept of accommodation is essential.	19,21,50,51
Dynamic visual acuity	Dynamic visual acuity refers to the capacity to see and recognise details of a moving object. It involves the capacity to perceive clearly and accurately when both the observer and the object are in motion.	19,52,53
Depth perception	Depth perception is the capacity to sense the absolute or relative distances between objects and the observer.	19,37,54
Colour discrimination	Visual colour discrimination is the ability of the visual system to distinguish between different colours based on hue, saturation and brightness. It enables accurate perception and differentiation of colours in the environment.	55,56,57,58

Note: Please see the full reference list of the article, Mathe N, Millard L, Breukelman GJ, Exploring gender differences in visio-spatial intelligence and gaze behaviour: A review of existing research. Afr Vision Eye Health. 2026;85(1), a1098. https://doi.org/10.4102/aveh.v85i1.1098, for more information.

Gender differences in visual skills are typically categorised into two main areas: visual hardware and visual software.[20] Visual hardware refers to the physiological and anatomical aspects of the visual system, such as retinal structure and brain pathways involved in processing visual stimuli.[20] In contrast, visual software pertains to the cognitive and perceptual processes involved in interpreting and using visual information.[20] Though some studies indicate significant gender differences in these categories, others report minimal or no differences.[7,21] These categorisations help us understand how biological and cognitive factors contribute to differences in visual abilities.[12,22]

TABLE 3: Gender differences in gaze behaviour.

Visual skills	Description	References
Saccadic eye movements	The ability to see objects clearly and sharply depends on saccades, which are quick eye movements that direct the region of greatest visual acuity towards the fovea.	22,59,60,61,62,63
Fixation	The term fixation/gaze refers to the process in which the eyes focus on a specific point, allowing for the collection of detailed visual information.	19,64,65,66
Eye tracking	Eye-tracking visual skills have the ability to accurately monitor and interpret eye movement while focusing on visual inputs. This skill entails determining where, when and how long someone looks at specific objects, locations or features in their environment.	18,67,68
Quiet eye	Quiet eye is defined as the final steady gaze or fixation on a specific target or location within the task setting, occurring within 3 degrees of visual angle and lasting at least 100 milliseconds before a movement begins.	69,70,71
Gaze cueing	Gaze cueing involves the automatic redirection of attention towards the direction someone else is looking and is an important aspect of social attention.	18,72,73
Gaze shifting	Gaze shifting is the mechanism by which the eyes move from one point to another, primarily through saccadic movements, allowing different parts of the visual scene to be brought into sharp focus via the fovea.	74,75,76

Note: Please see the full reference list of the article, Mathe N, Millard L, Breukelman GJ, Exploring gender differences in visio-spatial intelligence and gaze behaviour: A review of existing research. Afr Vision Eye Health. 2026;85(1), a1098. https://doi.org/10.4102/aveh.v85i1.1098, for more information.

Gender differences in visual software skills

Speed of recognition

While some evidence suggests gender-based differences in processing speed, such claims require scrutiny. For instance, although Mathe et al.[4] report variability in recognition speeds between men and women, these findings are often generalised without accounting for task specificity or individual variability. Studies noting that women recognise faces and emotional expressions more quickly[23,24] tend to associate this with social cognition, but such conclusions may overlook confounding variables such as sociocultural conditioning and sample diversity. Conversely, the observation that men excel in dynamic spatial environments[25] may reflect gendered experiences or training rather than innate ability. However, other research indicates that when variables such as age, task familiarity and training are taken into account, these disparities become less pronounced.[7,19] Gender effects do exist, but they are mitigated by context and experience.

Peripheral awareness

Research suggesting that women may exhibit heightened peripheral sensitivity[26,27,28] often frames this in terms of environmental monitoring and evolutionary roles such as caregiving or foraging. However, such interpretations risk reinforcing outdated gender essentialist views without accounting for broader contextual factors, such as modern environmental demands or task-specific training. David et al.[29] claim that boys demonstrate improved peripheral vision in traffic-related tasks, raising questions about how early exposure, familiarity with stimuli and expectations shape performance. In addition, hormonal and sociocultural influences are acknowledged,[30] yet these factors are rarely isolated or systematically examined across studies. Thus, while some sex-based trends in peripheral awareness are reported, attributing these to biological determinism may obscure the dynamic, plastic nature of visio-spatial processing shaped by learning, environment and cultural practices.

Eye–hand coordination

While men are often reported to outperform women in tasks requiring rapid, forceful movements, and women tend to excel in precision-based tasks,[31,32,33] these distinctions may oversimplify a complex interaction of biological factors, including hormonal influences and neuroanatomical differences, alongside sociocultural conditioning.[34] When practice and exposure are controlled, Orhan et al.[35] report no significant overall differences, highlighting the importance of opportunity and training. The body of research suggests that sex differences may be more reflective of experience and opportunity than innate ability, calling for more nuanced research designs that control for such confounds.

Visual memory

Women generally show advantages in object recognition, facial memory and recalling visual details, potentially linked to stronger verbal and episodic memory processes. Conversely, men often outperform women in spatial memory tasks, such as mental rotation and navigation.[12,36,37] While biological factors such as brain structure likely contribute, social and environmental influences also play critical roles in shaping these abilities.[38] Importantly, the considerable individual variability and overlapping performance suggest that gender differences should not be overstated.[39] The complex interplay of genetics, experience and context highlights the need for more refined research methods that account for these confounding factors, rather than attributing differences solely to sex.[39]

Concentration

Some research suggests men outperform women in dynamic visual tracking, whereas women may excel in sustained attention and detail-oriented tasks.[37,40,41] However, these findings are not universally replicable, indicating that gender effects on concentration may be context-dependent and moderated by task design. Neurobiological factors, including brain structure and hormonal influences, are often proposed

explanations,[30,42] but the extent to which these directly cause attentional differences remains unclear. In addition, sociocultural influences, such as differential exposure to certain activities during development, complicate interpretations.[43] When considered collectively, the literature demonstrates the highly task-dependent nature of attention-related differences.

Visual reaction time

Studies typically show men outperforming women in speed, particularly in rapid motor response tasks.[44,45] This gender difference is often attributed to biological factors such as hormonal influences like testosterone, greater muscle mass and neuromuscular efficiency.[19] However, these explanations risk oversimplification, as they may understate the contribution of environmental and experiential factors. For instance, men's greater involvement in reflex-enhancing sports and activities likely contributes to faster reaction times.[46,47] Conversely, women's superior performance in accuracy-focused and sustained attention tasks[48] suggests a trade-off between speed and precision rather than a simple speed advantage. Importantly, reaction time differences are further modulated by training, cognitive strategies and situational variables,[49] suggesting that gender effects are not fixed but rather context-dependent.

Gender differences in visual hardware skills

Accommodation facility

Some studies suggest women may exhibit superior accommodation ability, potentially because of ocular anatomical differences or hormonal influences.[19,21] However, conflicting evidence exists, with other research reporting no significant gender differences.[50] This inconsistency highlights substantial individual variability and suggests that external factors such as environmental conditions and measurement techniques could heavily influence results.[51] Gender disparities relating to accommodations are therefore yet unclear.

Dynamic visual acuity

Research indicates that men generally demonstrate superior dynamic visual acuity possibly because of a higher density of rod cells in the retina, which are more sensitive to motion.[52] Conversely, women tend to have a greater number of cone cells, supporting colour discrimination and fine detail resolution.[53] While hormonal influences such as testosterone and oestrogen have been proposed to modulate these visual processing differences,[19] the evidence remains largely correlational, and causal links are not well established.

Depth perception

Research shows that men generally demonstrate superior depth perception, especially in tasks requiring spatial awareness, consistent with broader findings showing male advantages in mental rotation and navigation tasks.[37] This male advantage has often been interpreted through an evolutionary lens, suggesting that spatial skills were favoured for activities such as hunting and navigation.[19] However, this perspective can oversimplify complex cognitive processes and may underrepresent the influence of cultural and educational experiences that shape spatial abilities. Conversely, women tend to outperform men in colour vision and fine detail discrimination, potentially reflecting evolutionary adaptations related to foraging and plant identification.[54] Nonetheless, these distinctions are not absolute, and considerable individual variability exists, underscoring the need for research that considers both biological and socioenvironmental contributors to depth perception.

Colour discrimination

Evidence suggests that men may exhibit poorer discrimination in the middle of the spectrum, particularly for greenish tones,[55,56] while women tend to show greater sensitivity to long-wavelength colours.[57] However, Rodríguez-Carmona et al.[58] found no significant gender differences when controlling for normal vision, highlighting the potential influence of genetic variability, especially X-chromosome linked factors. These mixed results suggest that colour discrimination differences between sexes may be less pronounced than commonly assumed and emphasise the importance of considering genetic, methodological and sample selection factors when interpreting such findings.

Gender differences in gaze behaviour

Saccadic eye movements

Research reports that men typically have faster saccadic velocities and shorter latencies than women;[59] these differences may stem from a combination of cerebral processing speed, hormonal influences and ocular motor control variations.[22] Conversely, some research indicates women may exhibit greater accuracy in specific saccadic tasks, potentially because of enhanced visual attention and cognitive processing.[60,61] Importantly, findings are not consistent across all studies, with some showing no significant gender differences,[62] highlighting how task demands, sample characteristics and methodological approaches can profoundly impact results.[63]

Fixation

Research indicates men generally exhibit shorter fixation durations and more frequent shifts in attention, whereas women tend to have longer fixations, suggesting a more detail-focused processing approach.[19,64,65] While neurological explanations point to men's greater reliance on right-hemisphere spatial processing and women's more bilateral hemisphere engagement during complex visual tasks,[66] these findings are limited by small sample sizes and the variability of task designs. In addition, the extent to which fixation differences translate into functional advantages remains unclear, emphasising the need for further research that controls for cognitive strategy and individual differences.

Eye tracking

Studies suggest that women exhibit stronger gaze-cueing effects, sustain longer eye contact and shift gaze more frequently during social interactions.[18,67] This pattern reflects greater attention to facial features and emotional cues, implying heightened sensitivity to social and contextual information.[68] In contrast, men typically display a more dispersed gaze pattern, focusing on object- or spatial-related information. However, these observed differences are influenced by both biological factors, such as hormonal levels and sociocultural conditioning, which complicates attributing causality.

Quiet eye

Research shows mixed findings[69] Jedziniak et al.[70] reported that male goalkeepers exhibit longer fixation durations than women during penalty shots, implying men may utilise more prolonged visual focus in high-pressure, goal-directed tasks; this finding is not consistent across studies. Lebeau et al.[71] found no significant gender differences in quiet eye when training and experience were controlled, highlighting that expertise and practice may be more critical factors than gender itself.

Gaze cueing

A study conducted by Bayliss et al.[18] found that women exhibit stronger gaze-cueing responses, suggesting greater sensitivity to social cues. Ohlsen, Van Zoest and Van Vugt[72] reported no significant gender differences in gaze cueing, despite the influence of facial dominance, indicating that gender may not be a primary factor. Furthermore, Bayliss and Tipper[73] argued that variables such as task demands and emotional context exert stronger effects on gaze cueing than gender. These mixed results, alongside varying methodologies and contextual influences, emphasise the complexity of gaze-cueing mechanisms and suggest that gender differences may be minimal or secondary to situational factors.

Gaze shifting

Findings are inconsistent.[74] Feng et al.[75] reported that women exhibit greater Event-Related Potential (ERP) amplitudes during attention-shift tasks, suggesting heightened cognitive engagement and possibly more efficient recruitment of brain areas related to visuo-spatial attention. However, Dong et al.[76] found no significant gender differences in visual behaviour during spatial orientation tasks, highlighting inconsistencies in the literature. These conflicting findings may result from differences in task complexity, measurement techniques or sample characteristics.

Limitations

Even though this review summarises many studies, a number of limitations should be noted. Firstly, because studies showing substantial gender differences are more likely to appear in the published literature than studies reporting null findings, publication bias may have had an impact on the overall patterns described. Secondly, there are significant methodological variations across the included research, including variations in sample demographics, cultural contexts, assessment instruments and definitions of gaze behaviour and visio-spatial intelligence. Inconsistencies across studies may be partially explained by this heterogeneity, which makes direct comparison challenging. Ecological validity is further limited by the fact that many studies use controlled laboratory activities that might not accurately reflect gaze behaviour or visual processing in the actual world. These drawbacks show that to support future findings, more standardised, long-term and contextually varied research is required.

Conclusion

This review shows that gender variations in gaze behaviour and visio-spatial intelligence are intricate, multidimensional and influenced by a combination of biological, cognitive and sociocultural factors. Women typically exhibit advantages in visual memory, peripheral awareness and socially oriented gaze behaviours, whereas men frequently show strengths in activities involving spatial orientation, mental rotation and dynamic visual processing. Crucially, these variations are not universal and frequently rely on context, training exposure, task type and methodological design.

This review illustrates how biological abilities and cognitive–perceptual strategies interact to influence visual behaviour across genders by integrating findings through the suggested visual hardware–visual software framework. This dual-framework approach gives future research a systematic direction and a firmer foundation for analysing discrepancies in earlier findings. To advance knowledge and promote equitable practices in educational, athletic and professional contexts, more research employing longitudinal, ecologically sound and culturally diverse methodology is required.

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CRediT authorship contribution

Nonkululeko Mathe: Conceptualisation, Formal analysis, Investigation, Methodology, Visualisation, Writing – original draft and Writing – review and editing. Lourens Millard: Conceptualisation, Formal analysis, Visualisation, Project administration and Writing – review and editing. Gerrit J. Breukelman: Visualisation, Supervision and Writing – review and editing.

All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

Ethical considerations

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Data availability

No new data were generated or analysed in this study. All data referenced are publicly available in the cited sources.

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