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Exploring Visual Search: Past and Current Insights

Görsel Aramayı Keşfetmek: Geçmiş ve Güncel Bilgiler

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Abstract

The visual search paradigm is a fundamental concept in cognitive psychology and neuroscience that seeks to understand how people perceive and recognize specific items in visually complex environments. It also serves as a fundamental tool for understanding cognitive mechanisms such as attentional processes, information processing, and environmental awareness. This paradigm is widely used in laboratory settings with consistent stimuli to gain a better understanding of the factors that influence visual perception and attention. In addition, visual search plays a significant role in our daily lives, particularly in social interactions. Although the phrase *visual search* has been used in scientific literature since the 1940s, its use as a technique in visual cognitive science research only began in the 1970s. It was not until the 1980s, pioneered by Tresiman and Galade, that visual search became a research field on its own, gaining significant popularity among visual perception scientists in the early 1990s. The current definition of visual search, which remains accepted and quoted to date, was introduced by Wolfe and Horowitz in 2008. Since then, studies in the field have continued to be carried out without slowing down. Today, the visual search paradigm not only remains an active research area of cognitive psychology and neuroscience but also a diagnostic approach in neurodevelopmental disorders such as autism spectrum disorder and attention-deficit / hyperactivity disorder. In this paper, we review the evolution of the visual search paradigm from the 1980s to the present, discussing the principles and mechanisms that have been accepted by the scientific community thus far. Additionally, we review studies that have been conducted using this paradigm on the topics of visual perception and attention, categorizing them into research areas.

Öz

Görsel arama, insanların görsel olarak zengin ortamlardaki belirli öğeleri nasıl algıladıklarını ve tanıdıklarını inceleyen, bilişsel psikoloji ve nörobilim için oldukça önemli bir paradigma olup, dikkat süreçleri, bilgi işleme ve çevresel farkındalık gibi bilişsel mekanizmaların anlaşılmasında temel bir araç olarak öne çıkar. Görsel arama paradigması, laboratuvar ortamlarında sabit ve kontrollü uyaranlar kullanarak görsel dikkati ve algıyı etkileyen çeşitli faktörleri anlamak için yaygın olarak kullanılan bir araştırma yöntemidir. Bununla birlikte, görsel arama, özellikle diğer insanlarla etkileşim söz konusu olduğunda, günlük yaşamımızda da son derece kritik bir rol oynamaktadır. *Görsel arama* kalıbının bilimsel literatürde kullanılmaya başlaması 1940'lara kadar giderken, bu paradigmanın görsel bilişsel bilim araştırmalarında bir teknik olarak kullanılması 1970'lerde gerçekleşmiştir. Görsel aramanın bir araştırma aracı olmaktan çıkması ve kendi başına bir araştırma alanına evrilmesi Tresiman ve Galade'nin öncülüğünde 1980'lerde gerçekleşmiş ve bu yeni araştırma alanı 1990'ların başlarında görsel algı bilimciler arasında oldukça popüler hale gelmiştir. Günümüzde halen kabul edilen ve sıkça alıntılanan tanımı, 2008 yılında Wolfe ve

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Horowitz tarafından literatüre kazandırılmış ve alandaki çalışmalar hız kesmeden gerçekleştirilmeye devam etmiştir. Günümüzde hala oldukça aktif bir araştırma alanı ve aracı olan görsel arama paradigması, bilişsel psikoloji ve nörobilim çalışmalarının yanında dikkat eksikliği ve hiperaktivite bozukluğu ve otizm spektrum bozukluğu gibi birçok farklı sinir gelişimsel rahatsızlıkta da tanısal bir yaklaşım olarak yaygın biçimde kullanılmaktadır. Bu derlemede, görsel arama paradigmasının 1980'lerden günümüze kadar olan evriminin, bilimsel toplulukça şimdiye kadar kabul edilmiş temel çalışma prensiplerinin ve mekanizmalarının üzerinden geçiyor ve görsel algı ve dikkat konu başlıkları altında bu paradigma kullanılarak gerçekleştirilmiş deneysel çalışmaları araştırma alanlarına ayırarak inceliyoruz.

Keywords Visual search · attention · perception · vision

Anahtar Kelimeler Görsel arama · dikkat · algı · görme

Exploring Visual Search: Past and Current Insights

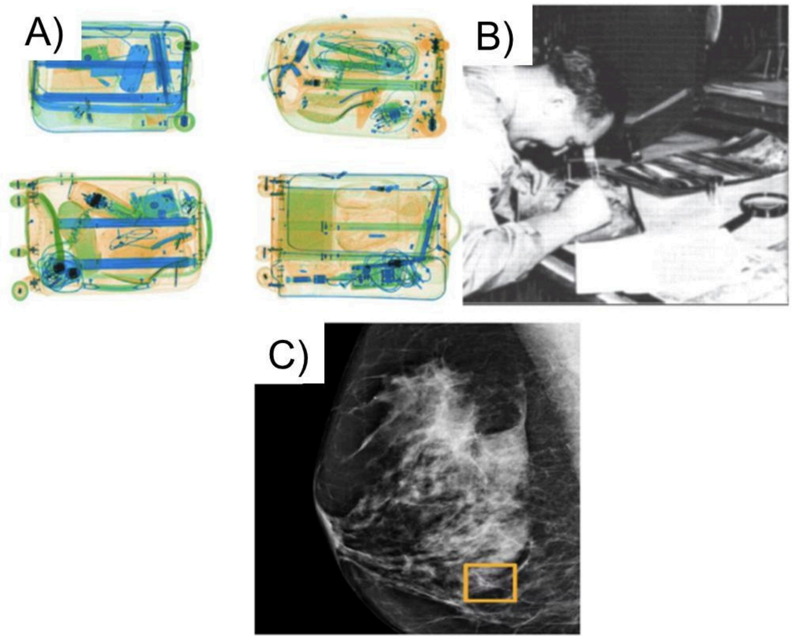
As we navigate our daily routines, we are constantly bombarded with various visual information, ranging from savoring a cup of coffee to scanning a crowded market for a specific item. However, the human eyes are unable to process all of this information simultaneously. This is where visual search becomes essential. Most of us are capable of shifting our attention to a target, whether it be the size and shape of a tiny wedge gleaming in traffic signals or a mole that has ventured from its burrow. Such behavior epitomizes what Horowitz and Wolfe (2008) called visual search; seeking out a particular object within a cluttered visual environment. Recognition and detection of objects in our environment are crucial, making the understanding of the mechanisms that drive visual attention and search essential to cognitive psychology and neuroscience. In this review, our objective is to provide a comprehensive evaluation of the existing literature, offering a detailed overview of key findings and insights on the evolution of the visual search paradigm from the 1980s to the present day. Additionally, we provide insight into how visual search paradigms have been used in research on visual perception and attention over the last two decades. We aim to combine insights from both theoretical models and applied studies, with a particular focus on clinical applications. By doing so, we provide an in-depth analysis of visual search by exploring its historical evolution, underlying mechanisms, practical applications, and impact across various disciplines, with a particular emphasis on its significance in clinical, practical, and theoretical contexts.

Visual Search

In numerous fields, the ability to locate or identify specific objects is of utmost importance, and the process of visual search is an indispensable part of the mechanisms that facilitate these processes. Used by both humans and animals, visual search plays a crucial role in locating prey and food, as well as in avoiding predators (Eckstein, 2011). Whether it is locating prey, identifying the correct bus stop in a crowded station, or searching for a particular product on a store shelf, visual search is imperative. Its significance extends to specialized fields, such as when airline security personnel scrutinize luggage for potential threats (see Figure 1A), photo interpreters analyze aircraft-captured images (Figure 1B), or radiologists examine images (Figure 1C) for signs of cancer (Donnelly et al., 2019; Eckstein, 2011; Meuter & Lacherez, 2016; Wolfe, 2021).

Figure 1

Some of the Fields that Employ Visual Search

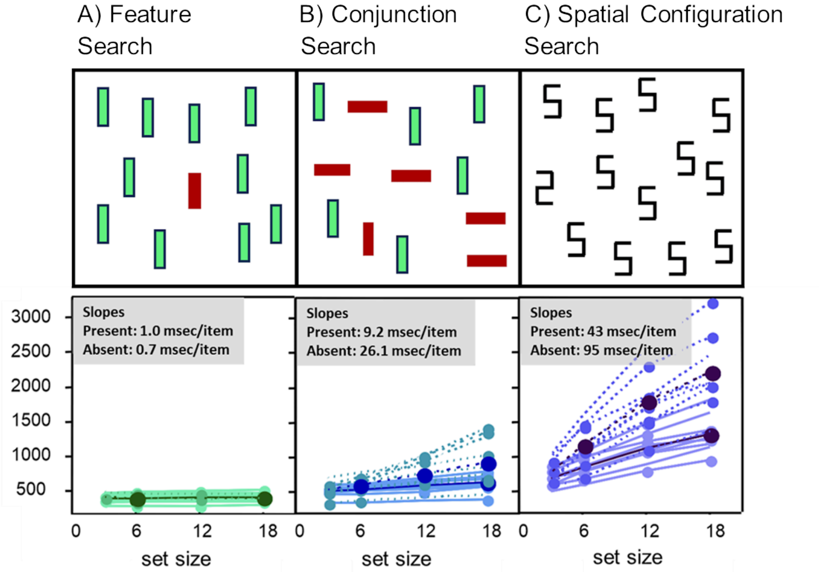


Note. A) X-ray images: Example of X-ray images of luggage. (Adapted from Donnelly et al., 2019). B) Aerial warfare images: A picture of a photo interpreter reviewing an image taken by a photorecon aircraft during the Second World War. (Adapted from Eckstein, 2011). C) X-ray images: Picture of a mammogram with spotted breast cancer. (Adapted from Faieq & Mijwil, 2022).

Previous studies indicate consistent patterns in how visual searches are conducted (Thornton & Gilden, 2007; Treisman & Gelade, 1980; Wolfe, 2010). Understanding these patterns is crucial for comprehending visual search and its underlying principles to improve our ability to detect potential security threats and enhance medical diagnosis as well as treatments. Upon a comprehensive review of the literature, it becomes evident that two primary strategies are commonly used in visual target searches: serial and parallel search (Moran et al., 2016; Thornton & Gilden, 2007; Treisman & Gelade, 1980; Wolfe, 2010). Serial search involves systematically examining each object in a visual array until the target is found, which can be obstructed by distracting objects (Eriksen & Yeh, 1985; Treisman & Gelade, 1980; Wolfe, 1998). In contrast, parallel search allows for the target's identification without examining each object within the array (Wolfe, 1998). Parallel search occurs if the unique visual features of the target are immediately distinguishable to the eye, a phenomenon known as the *pop-out effect*. The pop-out effect is characterized by the swift detection of a feature singleton stimulus among identical distractors (Hsieh et al., 2011; Treisman, 1982; Wolfe, 1994). Named as such due to its preattentive nature (Moran et al., 2016; Treisman & Gormican, 1988), the pop-out effect results in immediate recognition and can be induced by the target's distinctive features such as shape and color (Treisman & Gormican, 1988; Wolfe, 1998, 2010).

Figure 2

Experimental Search Displays for the Three Tasks



Note. In part A (Feature Search), the participants were asked to search for a red vertical rectangle among green vertical rectangles. In Part B (Conjunction Search), participants were asked to search for red vertical rectangles among green vertical and red horizontal rectangles. In the C (Spatial Configuration Search), participants searched for the number 2 among 5's. (Adapted from Wolfe et al., 2010).

Figure 2 depicts three visual search paradigms that gradually increase in difficulty. In the first paradigm (Figure 2A), participants had to perform a feature search by identifying a red vertical rectangle among green ones. The second paradigm (Figure 2B) involved a conjunction search, where the target was a red vertical rectangle embedded among green vertical and red horizontal rectangle distractors. Finally, in the third paradigm (Figure 2C), participants searched for the digital number 2 among 5's, which required a spatial configuration search. The difficulty in these paradigms arises from the similarities between the target and distractor stimuli. This results in various attentional guides in each visual array, such as color and orientation.

In the simple feature search (Figure 2A), the parallel deployment of attention to each stimulus is sufficient for the correct target identification as color is the only distinguishing feature between the target and the distractors, creating a pop-out effect. However, the latter two paradigms (Figure 2B, C) require a serial search to distinguish the target features, including color and orientation. In summary, feature search, as depicted in Figure 2A, involves the detection of a target that differs from the distractors on a single attribute, such as color. Conversely, conjunction search, as shown in Figure 2B, involves the identification of a target described by a combination of features, such as color and rotation differences, which appears to be more challenging and time-intensive than the feature search paradigm. The third paradigm is the most challenging as it includes increased similarities between the target and distractor stimuli. Therefore, the spatial configuration search requires a longer time for target identification than the second paradigm, as there are no other grouping factors, such as distinct color (Palmer et al., 2000; Wolfe, 2010). It is essential to acknowledge that the majority of visual search experiments carried out in laboratory settings utilize computer screens. While this method has its advantages and disadvantages, its largest defect lies in the inability of the stimuli presented on computer screens to replicate the dynamic and interactive stimuli found in the real world. For this reason, some researchers have replaced classical computer setups with real-world interactive scenarios and simulations to investigate visual search processes (Sauter et al., 2020). Combining virtual reality with a visual search paradigm has now become a common method (Ghose et al., 2018). Virtual reality (VR) allows researchers to measure how participants' performance would be affected by the 3D real-life environment, such as searching for a specific object on a crowded kitchen counter (Olk et al., 2018). This method increases the ecological validity of the visual search paradigms, making them more similar to real-life settings (Botch et al., 2023; Olk et al., 2018). However, it should be noted that although classical computer setups may result in less authentic portrayals of everyday visual search paradigms, these setups are highly effective at controlling variables in an experiment (Botch et al., 2021, 2023). This controlled environment is vital to examine the complexity of how we direct our attention in visual search paradigms (Wolfe, 2020). Comprehending the control of attention under these experimental limitations establishes a bridge with our exploration of visual search processes and the fundamental function of attention in perception and cognition (Stein et al., 2024).No matter if visual search is done through computer setups or VR, as our perception and cognitive processes are guided by our attention when searching for specific visual information, attention emerges as a crucial visual search component. When focusing on a particular visual item, our brain filters out unnecessary information to analyze the attended item more efficiently (Wolfe & Horowitz, 2017). In essence, attention acts as a spotlight in a complex visual array (Treisman, 1982). Thus, the effort to understand the underlying mechanisms of visual search commonly starts with exploring where and how we direct attention (Müller & and Krummenacher, 2006; Wolfe & Horowitz, 2017).

Visual Attention

Building on the current understanding of visual attention, it is evident that attention plays a crucial role in navigating through visual data (Kissler et al., 2009; Luck & Ford, 1998). Visual attention directs cognitive resources toward a particular aspect within the visual field (Treisman, 1982). Given the complexity of our visual surroundings, teeming with perceptual data, visual attention simplifies the intricacy and prevents information overload by honing in on pertinent details (Evans et al., 2011).

This selection process is determined by two guiding factors; bottom-up and top- down processing. In bottom-up processing, attention is automatically captured by stimuli in the environment, driven by their salience or novelty. On the other hand, top-down processing is a more controlled and goal-driven form of attention, influenced by cognitive factors such as expectations, knowledge, and goals (Katsuki & Constantinidis, 2014). Together, these processes work in tandem to successfully filter out useful and relevant information in our visual field for further processing. These processes demonstrate the dynamic relationship between cognitive mechanisms and the visual environment (Banerjee et al., 2017).

Bottom-up Processing

In the initial stages of visual processing, bottom-up processing involves the detection of low-level visual information such as shape, color, orientation, and motion (Wolfe & Horowitz, 2017). The human visual system seems to detect such low-level features in the visual array, generating a saliency map (Treisman & Gelade, 1980; Wolfe, 2010, 2021). A saliency map indicates visually significant areas within an image and therefore facilitates the identification of potential target locations by drawing attention to the standout regions (Katsuki & Constantinidis, 2014; Treisman & Gelade, 1980). Consequently, bottom-up guidance is stimulus-driven and occurs automatically due to the distinct properties of the target (Katsuki & Constantinidis, 2014).

Top-Down Processing

In contrast to bottom-up processing, top-down processing utilizes prior knowledge, expectations, and goals to direct attention to a specific area of the visual field (Treisman & Gelade, 1980; Wolfe, 2021). This form of processing relies on the subject- driven direction of attention toward objects with known features, where the target's features are recognized through past experiences. Thus, top-down guidance is subject-driven and based on the attentional direction toward objects with known features (Wolfe, 2010, 2021; Wolfe & Horowitz, 2017). Since the target's features are already known via previous experiences, the search process involves internally induced recognition (Katsuki & Constantinidis, 2014). Therefore, top-down processing enables a more focused search by leveraging prior knowledge to guide the attention toward objects with specific, previously encountered features, as exemplified in Figure 2B. During the search for a red vertical rectangle among green vertical and red horizontal rectangles, participants use a top-down approach as they search for a target that corresponds to a particular pattern. This is in contrast to a purely bottom-up approach, which relies solely on the visual features of the stimuli. As researchers interested in attentional processes explore the combination of both bottom-up and top-down processes in visual attention (Quinlan, 2003; Treisman & Gelade, 1980; Wolfe, 1994, 2020, 2021; Wolfe et al., 1989), it is essential to consider the most significant visual attention theories.

Feature Integration Theory

Feature integration theory (FIT) was introduced in 1977 by Treisman et al. and further developed in 1980, which provides a comprehensive framework for understanding visual search processes. FIT postulates a two-stage mechanism for the perceptual integration of visual features. The first stage, or the *preattentive stage*, operates automatically and in parallel, effortlessly recognizing fundamental features such as color, size, and orientation independently in a feature map (Quinlan, 2003; Wolfe et al., 1989). Through this parallel processing, the visual system can rapidly and efficiently extract elementary visual information from the environment.

The second stage, known as the *focused attention stage*, involves integrating these fundamental features to perceive an object as a coherent whole (Zhuang Cai et al., 2015). During this stage, attention is selectively directed to a specific location based on the features detected in the preattentive stage. The integration of these features into a coherent whole facilitates the recognition and understanding of complex visual stimuli. FIT emphasizes the dynamic interplay between automatic parallel processing and controlled sequential feature integration, elucidating how our perceptual system organizes and interprets the visual world. Empirical support for FIT is evident in its application to Balint's syndrome, a neurological disorder that disrupts an individual's ability to perceive objects holistically (Robertson et al., 1997). Individuals with Balint's syndrome struggle with the focused attention stage of feature integration, experiencing difficulties in combining individual features into a coherent whole (Arend & Henik, 2017; Cinel & Humphreys, 2006; Dalrymple et al., 2013; Gillebert & Humphreys, 2010; Humphreys et al., 2009; Pedrazzini et al., 2016). This empirical evidence reinforces the importance of FIT as a possible explanation for the importance of integrating visual features to achieve a coherent representation of the whole.

Guided Search Model

The guided search model (GS) was introduced as an alternative to FIT by Wolfe and colleagues in 1989. Initially, with this model, researchers proposed that the subsequent serial search is guided by the information gathered during the initial parallel processes, mirroring FIT in terms of the preattentive and attentive stages (Wolfe et al., 1989). The model has evolved with recent data (Wolfe, 1994), providing a clearer perspective on the mechanisms involved in visual search.

The next version of the guided search model (GS2) proposes that feature searches with high target-distractor differences exhibit *parallel search* behavior, while conjunction search is generally less effective (Nordfang & Wolfe, 2014; Wolfe, 1994, 2007, 2021; Wolfe & Gancarz, 1997). Moreover, conjunction search efficiency decreases as stimulus salience decreases, and the visual search becomes *serial* when basic feature information is absent (Wolfe, 1994).

In the third version of the guided search model (GS3), eye movements and covert attentional deployments at different eccentricities were included to achieve a more realistic model of human visual search behavior (Wolfe & Gancarz, 1996). GS3 proposes the presence of an activation map based on preattentive feature maps that are created according to attentional control. The featural information is then checked at an identification stage, where whether the current stimulus is the target or not is being decided. If the stimulus is not the target, the system opens up to judge another stimulus in the environment and repeats the attention-controlled process. To move to another stimulus, eye movements and thus a saccade map is needed, where a saccade map is a weak copy of the activation map. In every cycle of the system, the eyes move to the point in the saccade map with the highest activation. Because foveal (small eccentricity) information is presented more compared to peripheral (large eccentricity) information in the feature maps, the highest activation as well as the resulting eye movement is toward the items at the small eccentricity (Wolfe & Gancarz, 1996). Even though GS3 has been called "something of a dead end" by Wolfe in his GS6 manuscript 25 years later (Wolfe, 2021), it was a valuable introduction to the role of eye movements and covert attentional deployments in the guided search models at the time.

In 2007, Wolfe proposed an updated version, Guided Search 4.0, pointing out a bottleneck in visual search paradigms. This version proposed a selective attention- governed bottleneck between the initial stage of parallel feature processing and the latter stage of object recognition processes, challenging the notion of immediate object recognition present in the former versions. Wolfe questioned the duration of selected attention on a previously identified item, highlighting the need for attention in binding preattentive features, such as color and orientation, into a coherent object, such as a horizontal red bar (Wolfe, 2007). The most recent version of the guided search model (GS6) by Wolfe (2021) suggests that attention is *guided* through a *priority map*, prioritizing visual information from the most promising to the least. This priority map is created by five types of attentional guidance: (1) top-down feature guidance, (2) bottom-up feature guidance, (3) prior history (e.g., priming), (4) reward, and (5) scene syntax and semantics (Wolfe & Horowitz, 2017).

As mentioned, bottom-up processing is an automatic, stimulus-driven way for the human visual system to directly use low-level features like shape and color to identify significant areas within an image. On the other hand, top-down processing directs attention based on prior knowledge, expectations, and goals. This process uses subject- driven guidance to focus on objects with familiar features, making the search itself an internally induced process relying on past experiences.

Individuals' subjective evaluations are closely related to their prior search history and reward. Studies have shown that specific colors or cues tend to attract more attention than others, although this can vary from person to person. Moreover, prior experience can create cues and cause certain features to pop out (Buscher et al., 2010; Wolfe & Horowitz, 2017). Different guidance sources, such as syntactic and semantic scene guidance, play a crucial role in real-world visual search paradigms. For instance, when searching for strawberries in a grocery store, it would be logical to check the fruit and vegetable section, as strawberries are often found there (syntactic scene guidance). Similarly, checking other berries or fresh produce aisles would make sense, as similar products are usually placed near each other (Wolfe & Horowitz, 2017). In Guided Search 6.0 (Wolfe, 2021), schematic representations were provided, enriching the guidance properties and noting that visual search concludes when the target cannot be found and signals reach a threshold.

Until now, we have discussed the theories and methods underlying the basis of visual search. These theories enriched our comprehension and facilitated advancements in various professions. However, they do not discuss the usage of the visual search paradigm in different research domains. In the next section, we will review multiple research domains to further examine the applications and implications of the visual search paradigm.

Visual Search in Different Domains of Research

Research on visual search has significantly contributed to our understanding of human perception and attention in various research areas, including objects (Greenberg et al., 2015; Hemström et al., 2019; Kershner & Hollingworth, 2022; Spelke, 1990), scenes (Epstein & Baker, 2019; Kershner & Hollingworth, 2022; Wolfe et al., 2011), and face perception (Hemström et al., 2019; Leopold & Rhodes, 2010; Tsao & Livingstone, 2008; Williams et al., 2005). Studies on object perception have revealed insights into the mechanisms underlying top-down and bottom-up processing (Leonard & Egeth, 2008; Van der Stigchel et al., 2009), feature detection and integration (Chan & Hayward, 2009; Wolfe et al., 2010; Wolfe, 2020), and search strategies such as parallel and serial search (Li et al., 2020; Moran et al., 2016; Tian et al., 2011). Similarly, research on face perception has contributed to the understanding of holistic processing (Jin et al., 2022; Kavšek et al., 2022; Richler et al., 2011), the influence of inversion on perception (Savage & Lipp, 2015; Vestner et al., 2021; Williams et al., 2005), and the perception of emotions (Frischen et al., 2008; Maccari et al., 2014; Savage et al., 2013, 2016; Williams et al., 2005). Moreover, the visual search paradigm has also been leveraged in other areas of research, such as clinical treatment studies (Chan et al., 2023; Eraslan Boz et al., 2023; Federici et al., 2023; Guilbert & Rochette, 2023; Nuthmann & Clark, 2023; Ueda et al., 2023), and investigations into the complexities of visual perception (Becker et al., 2023; Kazanovich & Borisyuk, 2017; Krakowski et al., 2015; Pan et al., 2021; Walshe & Geisler, 2022; Wu & Wolfe, 2022).

This review not only examines visual search theories but also explores the application of the visual search paradigm across multiple research domains, highlighting its dual role as both a tool in clinical research and a subject of investigation in perceptual studies. The perceptual studies reviewed in this article focus on the domains of eye movements (Hooge et al., 2022; Zelinsky, 2008; Zhou & Yu, 2021) to study face and emotion perception (Bachmann et al., 2024; Becker et al., 2011; Li et al., 2023; Horstmann et al., 2006; Plate et al., 2023; Saito et al., 2023). The visual search paradigm will also be reviewed as a clinical tool for studies on autism spectrum disorder (Abassi Abu Rukab et al., 2022; Almeida et al., 2010; Ambati et al., 2023; Doherty et al., 2018; Keehn & Joseph, 2016; Marciano et al., 2022; Torrado et al., 2016), attention deficit hyperactivity disorder (Canu et al., 2022; Guo et al., 2023a; Mullane & Klein, 2008; Privitera et al., 2024), and spatial neglect (Butler et al., 2009; Cox & Aimola Davies, 2020; Emerson et al., 2019; Llorens & Noé, 2016; Paladini et al., 2019; Ricci et al., 2016).

This review, therefore, enlightens the complex relations between visual perception, attention, and cognitive processes by synthesizing findings from various disciplines, while also demonstrating the effectiveness of the visual search paradigm in furthering theoretical comprehension and clinical applications.

Visual Search and Eye Movements

Attentional guidance plays a crucial role in shaping behavior in visual search paradigms (Chang & Egeth, 2019; Martin & Becker, 2018; Stein et al., 2024; Wolfe, 2021). One way to examine attentional guidance is to investigate how attention is allocated by monitoring eye movements (Zelinsky, 2008). These eye movements act as both indicators and tools for understanding shifts in attention (Gaspelin et al., 2017; Rao et al., 2002; Najemnik & Geisler, 2005). Visual search research frequently uses eye-tracking to examine the dynamics of eye movements, focus, and the consequent behavior (Hooge et al., 2022; Nowakowska et al., 2017). The basics of eye movement analysis involve identifying (a) fixations, during which the eyes remain still to gather information, and (b) saccades, the rapid eye movements that occur between fixations. These factors enable researchers to investigate various search strategies, such as whether individuals examine items sequentially (serial search) or process multiple items simultaneously (parallel search), as well as more complicated aspects of search strategies such as planning or memory usage (Hamblin-Frohman et al., 2022; Hoppe & Rothkopf, 2019; Zhou & Yu, 2021).

Zhou and Yu (2021) investigated the optimality of human search behavior by applying various Bayesian-based models to human eye movement statistics acquired in a visual search paradigm. In this study, eye movements were used to gain a deeper understanding of the suboptimal strategy employment with cost-minimizing features without decreasing the search performance. Their results revealed that the most accurate predictions of human behavior were generated by a non-optimal constrained continuous-time entropy-limit minimization model (CCTELM). This model suggests that a suboptimal but still effective eye movement strategy, which balances performance and cost, is used in human visual search, highlighting the significant contribution of saccade amplitude, saccade accuracy, and memory capacity (constraint factors incorporated in the CCTELM model) to better understand the visual search behavior.

Recently, by investigating visual search in an extended field of view (FoV) using virtual reality, Stein et al. (2024) focused on how head and eye movements influence search efficiency. Researchers conducted two experiments, where participants searched for salient (O) or less salient (T) targets among distractors (L). The targets were either inside or outside the initial FoV. The results showed that while salient targets facilitated faster detection when within the initial FoV, the same advantage was not preserved when the target entered the FoV due to head movements. Instead of using peripheral salience to guide gaze shifts, participants followed a pre-planned search strategy, often continuing in the same direction rather than adapting based on target salience. These findings suggest that traditional visual search models do not fully apply when active exploration beyond the initial FoV is required.

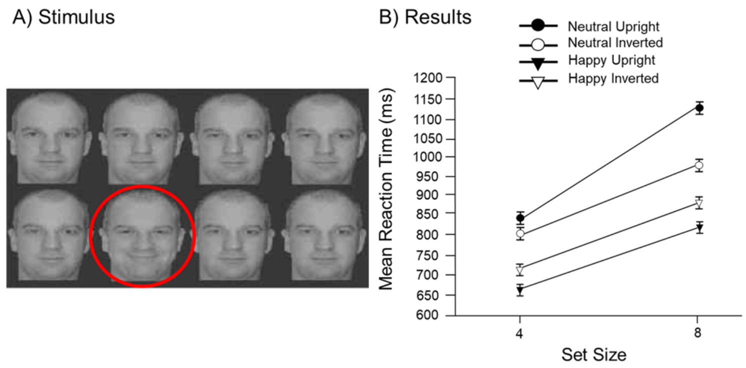
Visual Search in Face and Emotion Perception

Studies on face perception often concentrate on the recognition of emotional states. These research areas focus on the visual search regarding facial emotional expressions (Frischen et al., 2008; Maccari et al., 2014; Saito et al., 2023; Savage et al., 2013, 2016; Williams et al., 2005). The explanation for why different visual searches are conducted while examining various emotional expressions on faces is a recurrent topic of discussion. Previous research suggests that people are physiologically predisposed to recognize possible dangers; therefore, identifying furious faces in crowds is more effective (Hansen & Hansen, 1988; Horstmann et al., 2006). This alignment with our evolutionary wiring immediately identifies the possible dangers to survival. Results of the studies suggest that we are quicker in detecting angry faces than other facial expressions, termed the *angry face superiority* (Horstmann et al., 2006; Lipp et al., 2009a, 2009b). On the other hand, the *happiness superiority effect* has been proposed, suggesting that identifying happy faces is faster due to the importance of positive emotions during social interactions (Juth et al., 2005). Savage and colleagues (2013) conducted experiments to investigate the circumstances under which happy or angry face superiority occurs in a visual search. Their findings suggested that the specific features of the stimulus used in the study influenced the observed superiority effect in visual search. For example, the visibility of teeth on the faces of the stimuli may play a crucial role in attracting attention, affecting the superiority effect in visual search (Savage et al., 2013). On this note, Becker and colleagues (2011) conducted an experiment to investigate whether the detection speed of happy or angry faces could be influenced differently by the visibility of mouth and teeth using both real and computer-generated human faces. The results not only confirmed that happy expressions were more readily detected than angry ones but also revealed that this detection advantage extended beyond the simple visibility of teeth in smiles. These results were similar for both real and computer-generated faces. The face stimuli with closed lips were identified more rapidly and accurately than their angry counterparts. Finally, by analyzing the participants' strategies in the visual search, researchers demonstrated that participants often employed a serial search when identifying expressive faces. Moreover, participants consistently showed faster and more accurate detection of happy faces compared to angry faces. Ultimately, the study challenged the notion of a preattentive danger detection mechanism for angry expressions, suggesting that the enhanced recognition of happy faces in visual search paradigms may be a result of practiced social interactions, making it a more efficient process (Becker et al., 2011).

In another experiment (Williams et al., 2005), participants were instructed to locate a happy or neutral face while being presented with inverted or upright face stimuli in target-absent and target-present trials on computer screens (Figure 3A). The findings indicate that participants found it easier to locate happy upright faces among neutral upright face distractors compared to where neutral faces were targets and happy faces were distractors (Figure 3B). The inversion effect disrupts expression analysis, meaning that inversion prevents the attentional advantage for happy faces (Williams et al., 2005). This inversion effect explains why it was easier to locate upright happy face targets among neutral face distractors compared to locating inverted happy face targets among neutral face distractors. Additionally, it has been found that face inversion disrupts the holistic perception of a face, causing faces to be processed more locally (McKone & Yovel, 2009; Savage & Lipp, 2015; Silva et al., 2011; Tanaka & Farah, 1993; Tanaka et al., 2023). Researchers indicate that inverted happy face targets can be found more quickly than inverted neutral face targets, which may also account for the difference in reaction times between inverted neutral face and happy face targets.

Figure 3

An Example of the Experimental Stimulus



Note. An example of the experiment's stimulus is shown as a happy face (target) among seven neutral faces (distractors) on the left-hand side. The plot on the right-hand side shows how reaction time increases as the set size increases and the target stimuli type differentiates. (Adapted from Williams et al., 2005).

Savage and Lipp (2015) examined the effect of face inversion on the detection of emotional faces using a visual search paradigm. They investigated emotion detection for upright and inverted faces in six different experiments using various face stimuli databases. They found that face superiority affected both angry and happy facial expressions regardless of whether the face was upright or inverted. These results suggest that face inversion did not significantly interfere with the visual search for emotional expressions. Their findings, which are also in line with those of Williams and colleagues (2005), indicated that feature-based explanations are more likely and that holistic processing is not required when perceiving a face (Lipp et al., 2009b; Savage & Lipp, 2015; Wilkinson et al., 2008).

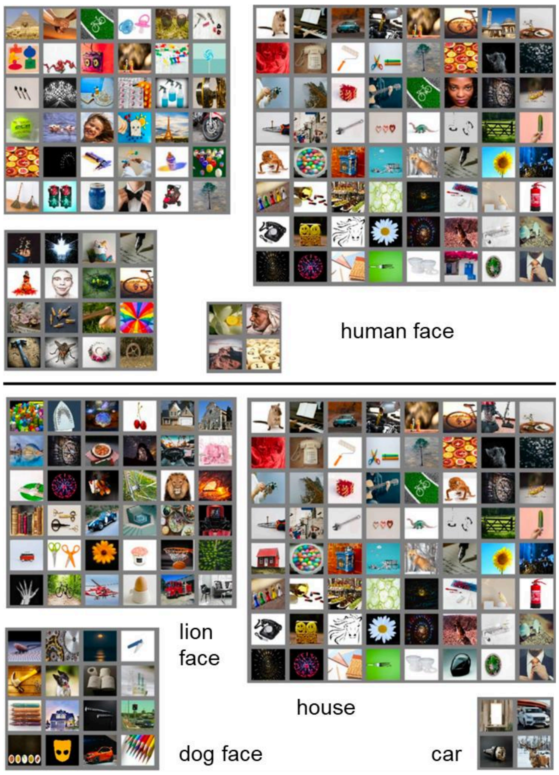
Visual Search in Autism Spectrum Disorders

Autism spectrum disorder (ASD), colloquially referred to as autism, is a common neurodevelopmental condition characterized by compromised social communication, deviant behavioral patterns, sensory malfunctions, and repetitive behaviors or interests (Almeida et al., 2010; Hirota & King, 2023; Keehn & Joseph, 2016; Lian et al., 2023; Memari et al., 2014; Wang et al., 2014; Zhou et al., 2023). The phenotypic heterogeneity of ASD poses a significant challenge, demanding further research, as it inhibits the development of standardized therapeutic approaches (Buch et al., 2023; Hassan & Mokhtar, 2019; Keehn et al., 2023; Masi et al., 2017; Mottron & Bzdok, 2020; Zhou et al., 2023).The previous research on individuals with ASD indicated that they tend to perceive sensory stimuli differently than individuals with neurotypical development (Burns et al., 2017; Dellapiazza et al., 2018; Hadad & Yashar, 2022; Jassim et al., 2021; Robertson & Baron-Cohen, 2017). Individuals with ASD were faster and more efficient in visual search compared to typically developed individuals, which is supported by their increased ability to process features (Gliga et al., 2015; Joseph et al., 2009; Kaldy et al., 2016; O'Riordan & Plaisted, 2001; Plaisted et al., 1998). Additionally, this enhanced perception of features appears to be linked to the severity of their autism symptoms (Gliga et al., 2015; O'Riordan & Plaisted, 2001). Moreover, research suggests that their advantage in processing features might be due to their attentional focus rather than enhanced perceptual abilities, which could be a result of over-focusing or their restricted interests in general (Kaldy et al., 2016). In contrast, some studies suggest that individuals with ASD have slower and less efficient visual search performance under different conditions, such as categorical search or multiple conjunction search tasks (Doherty et al., 2018; Keehn & Joseph, 2016; Torrado et al., 2016). Alternatively, there may not be a significant correlation between ASD symptoms and visual search abilities (López Pérez et al., 2019; Marciano et al., 2022).

As aforementioned, faces are an essential social stimulus and play a crucial role in human communication and social interactions. The difficulties in recognizing faces are frequently observed in children with ASD (Dawson et al., 2005; Golarai et al., 2006; Minio-Paluello et al., 2020); However, the exact reason behind these difficulties remains uncertain. Researchers tested children with ASD and neurotypical children on their ability to detect faces and objects using a visual search paradigm. This paradigm included human or animal faces and objects from different categories, such as houses or cars (Figure 4).

Figure 4

Example of Display Arrays Used in a Face Detection Task



Note. The participants were obligated to perform a visual search to detect and indicate the presence of face stimuli embedded between stimuli from other categories. (Adapted from Abassi Abu Rukab et al., 2022).

Participants were asked to detect the target face stimulus (Abassi Abu Rukab et al., 2022). The results showed that both children with ASD and neurotypical children detected human faces faster than any other category. Although minor, children with ASD had a significantly greater set size slope compared with neurotypical children, meaning that they had a larger dependence on set size while searching for human faces. This result suggests that the pop-out effect for human faces might not be as evident in children with ASD. Overall, children with ASD had significantly longer reaction times in every category (Abassi Abu Rukab et al., 2022).

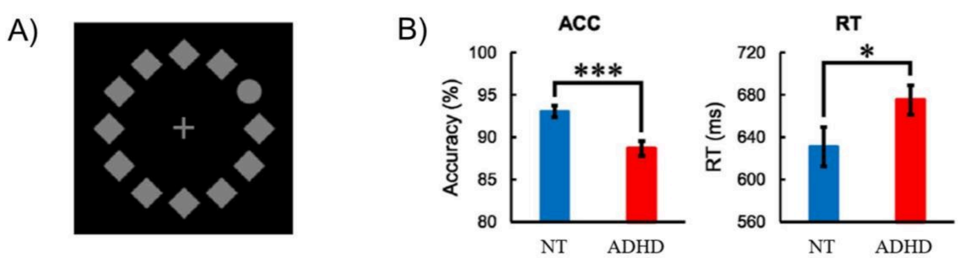
Visual Search in Attention-Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects approximately 5% and 3% of children and adults worldwide, respectively (Bellato et al., 2023; Slater et al., 2022). ADHD typically develops during childhood and may continue into adulthood (Guo et al., 2023a; Mayer et al., 2021; McLoughlin et al., 2010; Privitera et al., 2024). It is characterized by several behavioral symptoms including hyperactivity, impulsivity, agitation, and inattentiveness (Ortega et al., 2013; Privitera et al., 2024; Skalski et al., 2021; Türkan et al., 2016). ADHD may also include deficits in social interactions, restlessness, and repetitive or restrictive behavior (Seernani et al., 2021). Cognitively, ADHD is also related to deficits in temporal processing, arousal and regulation activation, working memory, temporal selective attention, and generalized cognitive control deficits across domains and processes (Donnadieu et al., 2015; Guo et al., 2023a; Laasonen et al., 2012; Michelini et al., 2022).

Given the high prevalence of ADHD and its negative impact both on behavior and cognition, it has been the focus of a large amount of research that has investigated its etiology and the neuroanatomical basis (Canu et al., 2022; Guo et al., 2023a, 2023b; Seernani et al., 2021; Türkan et al., 2016). Such studies aim to enhance existing treatments and develop personalized approaches to address this condition more effectively (Michelini et al., 2022).Visual search is often used in ADHD research focusing on attentional control and eye movements to gain insight into the enhancement and suppression of the target and the distractor stimuli (Booth et al., 2005; Canu et al., 2022; Hazell et al., 1999; Mason et al., 2003, 2004; Mullane & Klein, 2008; Privitera et al., 2024). For instance, Guo and colleagues (2023b) focused on the neurophysiological aspects of visual search. They collected electrophysiological (EEG) data from two groups of children: seventy-two neurotypical children and ninety-six children diagnosed with ADHD. By examining the differences in brain oscillations between these two groups during target selection, researchers gained new insights into the neurobiological basis of visual search and visual attention impairments in ADHD. Figure 5A illustrates the visual task used in the study.

Figure 5

Illustration of the Task used in the Experiment along with the Subsequent Behavioral Results



Note. A) Example of a visual search paradigm trial where the participants were instructed to find the target stimulus (circle) among multiple distractor stimuli (squares) while maintaining central fixation. B) Accuracy (%) and reaction time (RT, msec.) results of the performed visual search paradigm for neurotypical children (NT) and for children with ADHD. Both for accuracy and RT, children with ADHD performed worse compared to NT children. (Adapted from Guo et al., 2023b).

Children with ADHD showed worse performance in accuracy and reaction times (Figure 5B), decreased theta synchronization (TS), and heightened posterior alpha lateralization (AL) compared to neurotypical children. Furthermore, the authors noted a concerning absence of a positive correlation between the posterior AL and the middle-frontal TS in comparison to neurotypical children. This suggests a potential reduction in the functional connectivity between these regions, leading to poor executive control and a lack of top- down cognitive control. Utilizing the visual search paradigm combined with behavioral and electrophysiological measurements, Guo and colleagues (2023b) shed light on the developmental characteristics of visual attention in children with ADHD, indicating that their brain maturation may differ from that of neurotypical children.

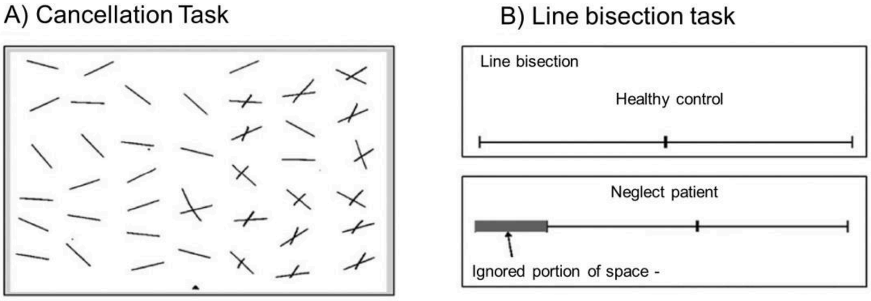
Visual Search in Spatial Neglect

Spatial neglect (also referred to as neglect, unilateral spatial neglect, or hemispatial neglect) is a syndrome in which an individual fails to report, respond, or orient to a stimulus in one or rarely both of their sensory fields (Heilman et al., 2000; Nakatani et al., 2013; Ting et al., 2011). This is caused by contralateral damage to the hemispheres due to stroke, traumatic brain injury, neoplasia, or aneurysm (Cox & Aimola Davies, 2020; Cubelli, 2017, 2023; Paladini et al., 2019; Sarwar & Emmady, 2023). Numerous visual search studies have shown that damage to the right hemisphere is more likely to cause neglect in the left sensory field than damage to the left hemisphere in the right sensory field (Butler et al., 2009; Cox & Aimola Davies, 2020; Morris et al., 2004; Ohmatsu et al., 2019; Sarwar & Emmady, 2023). In 2017, Cubelli re-defined neglect as a consistent asymmetry in processing spatial information, which has both positive and negative symptoms due to a cerebral lesion (Cubelli, 2017, 2023). Although spatial neglect may affect several sensory modalities (including auditory, olfactory, and haptic), the visual modality has been the primary focus of spatial neglect research due to its severity and relative ease of assessment (Barrett & Houston, 2019; Gutschalk & Dykstra, 2015; Vallar & Calzolari, 2018; Vangkilde & Habekost, 2010).

In accordance with the general definition of neglect, patients with visuospatial neglect fail to attend, respond, or orient themselves to the visual field that is contralateral to the damaged hemisphere (Cazzoli et al., 2015). This can be readily assessed with neuropsychological assessments like cancelation (multi-target visual search), line bisection (LBT), or copying and drawing tests (Benjamins et al., 2019; Chechlacz et al., 2012; Ting et al., 2011; Vallar & Calzolari, 2018; Van der Stigchel & Nijboer, 2017). The cancelation test mostly involves the identification of multiple targets among numerous distractor stimuli, as in the classical visual search paradigms (Ting et al., 2011; Figure 6A), while the LBT test involves marking the midpoint of a given straight line (Benjamins et al., 2019; Figure 6B). In a multi-target cancelation (visual search) task, the participant had to cross out the full circles presented on the paper. Even though the participant performed the task successfully on the right visual field, they were unable to detect the target stimuli on the left visual field due to neglect (Chechlacz et al., 2012). Figure 6 displays two commonly utilized tests to measure the severity of neglect: cancelation and LBT (Cox & Aimola Davies, 2020; Luvizutto et al., 2020; Molenberghs & Sale, 2011).

Figure 6

Two Examples of Neurophysiological Tests to Assess Visuospatial Neglect



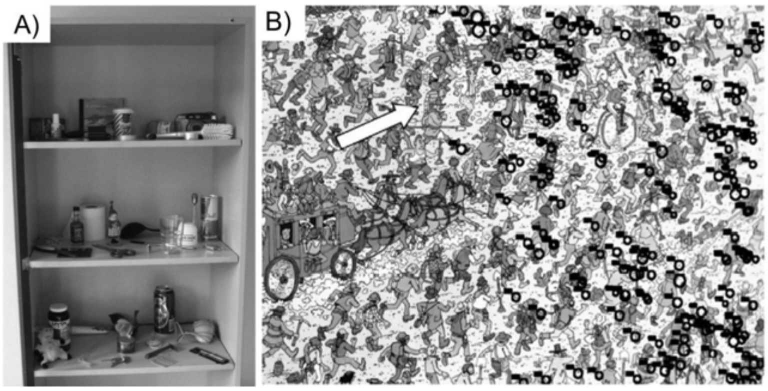
Note. A) Classic cancellation (visual search) task where the participant had to cross out the lines presented on the paper. As seen here, the participant's performance was successful on the right visual field, they were unable to detect the target stimuli on the left visual field due to neglect. B) A line bisection task (LBT), where the participants were instructed to mark the middle of the given line, was performed by a healthy (upper panel) participant and a visually neglect patient (lower panel). The neglect patient's marking is shifted to the right due to the ignored portion of space on their left visual field, compared to the healthy participant's marking. (Adapted from Ting et al., 2011).

Visual neglect can have significant functional ramifications if left untreated and not properly diagnosed (Ting et al., 2011; Vallar & Calzolari, 2018). Therefore, comprehensive research has been conducted since the 1940s up to the present, utilizing diverse methods and techniques (Battersby et al., 1956; Rizzolatti & Berti, 1994; Bisiach et al., 1983; Brain, 1941; Cubelli, 2017, 2023; Vallar & Bolognini, 2014). On this matter, visual search paradigms have become a popular choice for researchers due to their intricate nature, which emulates the complexities found within the natural visual environment (Behrmann et al., 2004; Cazzoli et al., 2015; Cox & Aimola Davies, 2020; Emerson et al., 2019; Llorens & Noé, 2016; Paladini et al., 2019; Ricci et al., 2016; Wilkinson et al., 2008).

Vangkilde and Habekost (2010) conducted visual search research to investigate the impact of prism adaptation on visual search performance in patients with visuospatial neglect. In their study, the visual neglect participants were divided into two groups. One group was trained with prismatic goggles, which shifted their visual fields ten degrees to the right, while the other group received only general cognitive rehabilitation as a control group. After the training, the participants performed three visual search experiments before and after the training and five weeks after the second session to assess the long-term effects of the prism therapy. The visual search paradigms involved stimuli such as a photo of everyday-life objects (Figure 7A) or an image taken from the Where's Wally book illustrations (Figure 7B).

Figure 7

Two Examples of Visual Search Stimuli from the Study of Vangkilde and Habekost



Note. A) One of the stimuli used in the naturalistic search task (the Cupboard test) was comprised of thirty (ten targets) everyday objects distributed to three shelves. B) One of the stimuli in the visual search paradigm (the Where's Wally test, white arrow indicating Wally's location) with the gaze fixation behavior (represented by circles) of one of the participants. (Adapted from Vangkilde & Habekost, 2010).

The analysis of the reaction time, accuracy, and eye-movement data showed significant improvements in the visual search performance; the participants were more accurate and faster. Researchers also showed an attenuation of the rightward bias, which was present before the prism therapy. With this study, Vangkilde and Habekost (2010) assessed the effectiveness of prism therapy as a clinical approach to treating patients with visuospatial neglect and demonstrated its success. Extensive research has been conducted on spatial neglect using a modified form of the visual search paradigm. For instance, by using visual search paradigms, Emerson and colleagues (2019) gained a deeper understanding of spatial neglect's neurological and functional characteristics, and evaluate the effectiveness of current and future treatment approaches. They discovered that there was a significant rightward bias in the target detection rates and visual field scanning performance. This rightward bias was also coupled with reduced search areas, indicating that hyper-attention affects not only the horizontal axis but also the vertical axis. It is now widely accepted that impairments in visual search performance are a key hallmark of visuospatial neglect (Cazzoli et al., 2015; Cox & Aimola Davies, 2020; Fellrath et al., 2012).

Discussion

Visual search has been the focus of numerous scientific studies. Initially used merely as a research paradigm, it has since become a subject of study. This transition has prompted a consolidation of understandings regarding the visual search paradigm. Early research on visual search primarily focused on distinguishing between parallel and serial search methods and their connections (Thornton & Gilden, 2007; Treisman & Gelade, 1980; Wolfe, 2010; Wolfe & Horowitz, 2008). These search methods are differentiated by how information is acquired and handled in a search task. Serial search methods require scanning through items one after another, while parallel search methods allow for simultaneous processing of multiple items (Eriksen & Yeh, 1985; Treisman & Gelade, 1980; Wolfe, 1998). There has been ample exploration and analysis of the relationship between these search methods and their impact on search efficiency. Using the visual search paradigm, research also provided insight into the relationship between the low-level features of stimuli (such as color and orientation) and their effects on attention, increasing our understanding of the underlying mechanisms that regulate search-related behavior (Chapman & Störmer, 2022; Hsieh et al., 2011; Kristjánsson et al., 2008; McCants et al., 2018; Moran et al., 2016; Nuthmann et al., 2021). For instance, research shows that salient features can attract attention, even if they are irrelevant to the task, reflecting the importance of bottom-up processing in the early phases of visual search (Gaspelin et al., 2017). Conversely, bottom-down influences, such as task goals or learned associations, can at times dominate top-down influences, particularly among experts (Ligeza et al., 2017). These findings have important implications for our understanding of perception and cognition and highlight the need for further investigation into the complex interactions between sensory inputs and attentional modulations in shaping our experience of the world. Moreover, understanding the interplay between these low-level features of the stimuli, mechanisms of attention allocation, and the consequent behavior is essential for developing effective interfaces and training programs in critical contexts, such as military operations or air traffic control.

Over the years, more and more research has examined models of visual search that investigate the relationships between search behaviors and their underlying neural mechanisms (Ball et al., 2013; Dugué et al., 2019; Ellison et al., 2007, 2014; Naderi et al., 2023; Nobre et al., 2003; Roberts et al., 2015; Talsma et al., 2010). Researchers have offered important perspectives on the underlying cognitive processes involved in visual search, shedding light on the various factors influencing search performance and the involved neural mechanisms. By exploring the complex interaction between low-level stimuli features and visual search, researchers have developed a more nuanced model (GS6) of visual search that can better explain the observed search behavior compared to earlier models. These insights have far-reaching implications for academic research and clinical applications, as highlighted in this article.

The visual search paradigm has gone through two primary models: FIT (1977) and GS1-GS6 (1989-2021). These models have undergone significant theoretical evolution over time. However, it is important to note that even the latest versions of the visual search models have room for improvements to be able to mimic naturalistic human search behavior (Wolfe, 2021). The GS6 offers a more comprehensive understanding of the core ideas of the previous versions and proposes more specific ideas for the impacts of scene properties, internal search engines, and functional visual field(s) on the resulting search behavior. One significant limitation of visual search models (including GS6) is that they are tailored to artificial search behavior, where the target stimulus must be found within milliseconds, hundreds of times through blocks of trials. Therefore, further examination of the GS' application in naturalistic scenes (which will create search behaviors closer to the real-world searches) is required to investigate more complex search behaviors, such as quitting thresholds, subsequent search misses, and the marginal value theorem in foraging and navigation.

FIT (Treisman, 1977) and the GSs (Wolfe et al., 1989) have been crucial in understanding the underlying mechanisms of visual search. FIT suggests a two-stage process involving preattentive feature detection and focused attention, while the GS enhances this understanding by incorporating the interaction between goal-directed top-down and stimulus-driven bottom-up processes. For instance, in a chaotic environment, like a cluttered desk, FIT clarifies why certain features, such as the red color of a stapler, can stand out, whereas the GS6 explains how prior experiences or the contextual significance of office items refine our attention. However, real-world tasks often require the integration of these processes, highlighting the need to test these models in more naturalistic and dynamic settings. By incorporating scene syntax and reward associations, as emphasized in the GS, one could refine predictions regarding search behavior in real-life scenarios such as urban navigation or wildlife foraging. This review also explores various domains of research where visual search has made significant contributions, including object (Leonard & Egeth, 2008; Van der Stigchel et al., 2009), scene (Epstein & Baker, 2019), and emotion perception (Frischen et al., 2008; Maccari et al., 2014; Saito et al., 2023; Savage et al., 2013, 2016; Williams et al., 2005). These areas of study have provided insights into holistic processing (Jin et al., 2022; Kavšek et al., 2022; Richler et al., 2011), feature integration (Chan & Hayward, 2009; Quinlan, 2003; Zhuang Cai et al., 2015), and search strategies (Li et al., 2020; Moran et al., 2016; Tian et al., 2011), especially in the context of face perception and emotion recognition. Another aspect of this review is the discussion on visual search in individuals with ASD (Dellapiazza et al., 2018; Joseph et al., 2009; O'Riordan et al., 2001). The investigation of visual search capabilities in individuals with ASD offers valuable insights into how neurodiversity influences attentional processes. Research suggests that individuals with ASD are often better at recognizing small differences in patterns, a feat that is made possible through heightened perceptual sensitivity and attention to detail (Dakin & Frith, 2005; Kaldy et al., 2016; O'Riordan et al., 2001). However, these strengths can come with challenges, such as difficulties in holistic processing and task-switching (Doherty et al., 2018; Golarai et al., 2006). For instance, although individuals with ASD may outperform their neurotypical peers in pinpointing specific shapes within a cluttered array, they may struggle with global search tasks that require the integration of multiple features. Such studies expand our comprehension of the cognitive abilities of individuals with ASD, offering insight into tailored life interventions. These include the utilization of gamified training programs that focus on strengths rather than deficits. Future studies could benefit from longitudinal designs to examine how these abilities evolve over the lifespan and their implications for functioning in real-world contexts.

Conclusion

This review paper provides a comprehensive overview of visual search, encompassing its widely accepted mechanisms from the 1980s to the present, and underscoring its significance across the domains of visual perception and attention within the last two decades. Furthermore, this review paper stands out through its discussion of findings obtained from both theoretical studies and applied research, enabling us to gain a full view of visual search. By reviewing the foundational mechanisms of visual search and its practical applications, this review provides a deeper insight into how visual search paradigms address real-world challenges. The FIT and guided search models have inspired a cascade of visual search models. GS6 is universally heralded as the novel definitive model of search behavior and has been crucial in furthering our understanding of the functional interactions between attention and perception involved in visual search.

In conclusion, the visual search paradigm has attracted great interest and has advanced our understanding of human perception, attention, and cognition. Ongoing experimental designs and theoretical developments provide deeper insights into the mechanisms involved in our navigation and perception of the visual world. Consequently, as empirical research and methodological technologies evolve, visual search models are transformed into increasingly accurate and reliable practical or clinical circumscriptions across all disciplines.

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References

Abassi Abu Rukab, S., Khayat, N., & Hochstein, S. (2022). High-level visual search in children with autism. *Journal of Vision*, *22*(9), 6. https://doi.org/10.1167/jov.22.9.6

Almeida, R. A., Dickinson, J. E., Maybery, M. T., Badcock, J. C., & Badcock, D. R. (2010). Visual search performance in the autism spectrum II: The radial frequency search task with additional segmentation cues. *Neuropsychologia*, *48*(14), 4117– 4124. https://doi.org/10.1016/j.neuropsychologia.2010.10.009

Ambati, V. N. P., Reimer, J. F., Escalante, G., & Saucedo, F. (2023). Atypical gaze behavior in children with high functioning autism during an active balance task. *Annals of Applied Sport Science*, *11*(2), 0–0. https://doi.org/10.52547/aassjournal.1143

Arend, I., & Henik, A. (2017). What can illusory conjunctions reveal about synaesthetic bindings? *Multisensory Research*, *30*(3–5), 235–251. https://doi.org/10.1163/22134808-00002555

Bachmann, H. P., Japee, S., Merriam, E. P., & Liu, T. T. (2024). Emotion and anxiety interact to bias spatial attention. *Emotion (Washington, D.C.), 24(4),* 1109-1124. https://doi.org/10.1037/emo0001322

Ball, K., Lane, A. R., Smith, D. T., & Ellison, A. (2013). Site-dependent effects of tDCS uncover dissociations in the communication network underlying the processing of visual search. *Brain Stimulation*, *6*(6), 959–965. https://doi.org/10.1016/j.brs.2013.06.001

Banerjee, S., Grover, S., & Sridharan, D. (2017). Unraveling Causal Mechanisms of Top-Down and Bottom-Up Visuospatial Attention with Non-invasive Brain Stimulation. *Journal of the Indian Institute of Science*, *97*, 451–475. https://doi.org/10.1007/s41745-017-0046-0

Barrett, A. M., & Houston, K. E. (2019). Update on the clinical approach to spatial neglect. *Current Neurology and Neuroscience Reports*, *19*(5), Article e25. https://doi.org/10.1007/s11910-019-0940-0

Battersby, W. S., Bender, M. B., Pollack, M., & Kahn, R. L. (1956). Unilateral "spatial agnosia" ("inattention") in patients with cerebral lesions. *Brain*, *79*(1), 68–93. https://doi.org/10.1093/brain/79.1.68

Becker, D. V., Anderson, U. S., Mortensen, C. R., Neufeld, S. L., & Neel, R. (2011). The face in the crowd effect unconfounded: Happy faces, not angry faces, are more efficiently detected in single- and multiple-target visual search tasks. *Journal of Experimental Psychology: General*, *140*(4), 637–659. https://doi.org/10.1037/a0024060

Becker, S. I., Grubert, A., Horstmann, G., & Ansorge, U. (2023). Which processes dominate visual search: Bottom-up feature contrast, top-down tuning or trial history? *Cognition*, *236*, Article e105420. https://doi.org/10.1016/j.cognition.2023.105420

Behrmann, M., Ebert, P., & Black, S. E. (2004). Hemispatial neglect and visual search: A large scale analysis. *Cortex*, *40*(2), 247–263. https://doi.org/10.1016/S0010- 9452(08)70120-5

Bellato, A., Perna, J., Ganapathy, P. S., Solmi, M., Zampieri, A., Cortese, S., & Faraone, S. V. (2023). Association between ADHD and vision problems. A systematic review and meta-analysis. *Molecular Psychiatry*, *28*(1), 410–422. https://doi.org/10.1038/s41380-022-01699-0

Benjamins, J. S., Dalmaijer, E. S., Ten Brink, A. F., Nijboer, T. C. W., & Van Der Stigchel, S. (2019). Multi-target visual search organisation across the lifespan: Cancellation task performance in a large and demographically stratified sample of healthy adults. *Aging, Neuropsychology, and Cognition*, *26*(5), 731–748. https://doi.org/10.1080/13825585.2018.1521508

Bisiach, E., Bulgarelli, C., Sterzi, R., & Vallar, G. (1983). Line bisection and cognitive plasticity of unilateral neglect of space. *Brain and Cognition*, *2*(1), 32–38. https://doi.org/10.1016/0278-2626(83)90027-1

Booth, J. R., Burman, D. D., Meyer, J. R., Lei, Z., Trommer, B. L., Davenport, N. D., Li, W., Parrish, T. B., Gitelman, D. R., & Mesulam, M. M. (2005). Larger deficits in brain networks for response inhibition than for visual selective attention in attention deficit hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *46*(1), 94–111.

https://doi.org/10.1111/j.1469-7610.2004.00337.x

Botch, T. L., Garcia, B. D., Choi, Y. B., & Robertson, C. E. (2021). *Individual differences in visual search performance extend from artificial arrays to naturalistic.* bioRxiv. https://doi.org/10.1101/2021.10.15.464609

Botch, T. L., Garcia, B. D., Choi, Y. B., Feffer, N., & Robertson, C. E. (2023). Active visual search in naturalistic environments reflects individual differences in classic visual search performance. *Scientific Reports*, *13*(1), Article e631. https://doi.org/10.1038/s41598-023-27896-7

Brain, W. R. (1941). Visual disorientation with special reference to lesions of the right cerebral hemisphere. *Brain*, *64*(4), 244–272. https://doi.org/10.1093/brain/64.4.244

Buch, A. M., Vértes, P. E., Seidlitz, J., Kim, S. H., Grosenick, L., & Liston, C. (2023). Molecular and network-level mechanisms explaining individual differences in autism spectrum disorder. *Nature Neuroscience*, *26*(4), 650–663. https://doi.org/10.1038/s41593-023-01259-x

Burns, C. O., Dixon, D. R., Novack, M., & Granpeesheh, D. (2017). A systematic review of assessments for sensory processing abnormalities in autism spectrum disorder. *Review Journal of Autism and Developmental Disorders*, *3*(4), 209–224. https://doi.org/10.1007/s40489-017-0109-1

Buscher, G., Dumais, S. T., & Cutrell, E. (2010). The good, the bad, and the random: An eye-tracking study of ad quality in web search. In *Proceedings of the 33rd International ACM SIGIR Conference on Research and Development in Information Retrieval* (pp. 42–49). Association for Computing Machinery. https://doi.org/10.1145/1835449.1835459

Butler, B. C., Lawrence, M., Eskes, G. A., & Klein, R. (2009). Visual search patterns in neglect: Comparison of peripersonal and extrapersonal space. *Neuropsychologia*, *47*(3), 869–878. https://doi.org/10.1016/j.neuropsychologia.2008.12.020

Cai, Z.,Li, Y. N., Zheng, X. S., & Zhang, K. (2015, April). Applying feature integration theory to glyph-based information visualization. *In 2015 IEEE Pacific Visualization Symposium (PacificVis)* (pp. 99–103). IEEE. https://doi.org/10.1109/PACIFICVIS.2015.7156363

Canu, D., Ioannou, C., Müller, K., Martin, B., Fleischhaker, C., Biscaldi, M., Beauducel, A., Smyrnis, N., van Elst, L. T., & Klein, C. (2022). Visual search in neurodevelopmental disorders: Evidence towards a continuum of impairment. *European Child & Adolescent Psychiatry*, *31*(8), 1–18. https://doi.org/10.1007/s00787-021-01756-z

Cazzoli, D., Rosenthal, C. R., Kennard, C., Zito, G. A., Hopfner, S., Müri, R. M., & Nyffeler, T. (2015). Theta burst stimulation improves overt visual search in spatial neglect independently of attentional load. *Cortex*, *73*, 317–329. https://doi.org/10.1016/j.cortex.2015.09.009

Chan, L. K. H., & Hayward, W. G. (2009). Feature integration theory revisited: Dissociating feature detection and attentional guidance in visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(1), 119–132. https://doi.org/10.1037/0096-1523.35.1.119

Chan, M. K.-L., Wong, C. L., Yu, K. P., & Tong, R. K.-Y. (2023). Examining eye tracking metrics and cognitive function in post-stroke individuals: A comparison of visual searching tasks between those with and without cognitive impairment. *Cerebrovascular Diseases (Basel, Switzerland)*, *53*(6), 683-692. https://doi.org/10.1159/000535756

Chang, S., & Egeth, H. E. (2019). Enhancement and suppression flexibly guide attention. *Psychological Science*, *30*(12), 1724-1732. https://doi.org/10.1177/0956797619878813

Chapman, A. F., & Störmer, V. S. (2022). Feature similarity is non-linearly related to attentional selection: Evidence from visual search and sustained attention tasks. *Journal of Vision*, *22*(8), Article e4. https://doi.org/10.1167/jov.22.8.4

Chechlacz, M., Rotshtein, P., Roberts, K. L., Bickerton, W. L., Lau, J. K., & Humphreys, G. W. (2012). The prognosis of allocentric and egocentric neglect: Evidence from clinical scans. *PloS one*, *7*(11), Article e47821. https://doi.org/10.1371/journal.pone.0047821

Cinel, C., & Humphreys, G. W. (2006). On the relations between implicit and explicit spatial binding: Evidence from Balint's syndrome. *Cognitive, Affective, & Behavioral Neuroscience*, *6*(2), 127–140. https://doi.org/10.3758/CABN.6.2.127

Cox, J. A., & Aimola Davies, A. M. (2020). Keeping an eye on visual search patterns in visuospatial neglect: A systematic review. *Neuropsychologia*, *146*, Article e107547. https://doi.org/10.1016/j.neuropsychologia.2020.107547

Cubelli, R. (2017). Definition: Spatial neglect. *Cortex*, *92*, 320–321. https://doi.org/10.1016/j.cortex.2017.03.021

Cubelli, R. (2023). Milestones in Cortex: Three Italian papers on spatial neglect. *Cortex*, *170*, 32-37. https://doi.org/10.1016/j.cortex.2023.09.012

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. *Neuron*, *48*(3), 497–507. https://doi.org/10.1016/j.neuron.2005.10.018

Dalrymple, K. A., Barton, J., & Kingstone, A. (2013). A world unglued: Simultanagnosia as a spatial restriction of attention. *Frontiers in Human Neuroscience*, *7,* Article e145. https://doi.org/10.3389/fnhum.2013.00145

Dawson, G., Webb, S. J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology*, *27*(3), 403–424. https://doi.org/10.1207/s15326942dn2703_6

Dellapiazza, F., Vernhet, C., Blanc, N., Miot, S., Schmidt, R., & Baghdadli, A. (2018). Links between sensory processing, adaptive behaviours, and attention in children with autism spectrum disorder: A systematic review. *Psychiatry Research*, *270*, 78–88. https://doi.org/10.1016/j.psychres.2018.09.023

Doherty, B. R., Charman, T., Johnson, M. H., Scerif, G., Gliga, T., & BASIS Team. (2018). Visual search and autism symptoms: What young children search for and co-occurring ADHD matter. *Developmental Science*, *21*(5), Article e12661. https://doi.org/10.1111/desc.12661

Donnadieu, S., Berger, C., Lallier, M., Marendaz, C., & Laurent, A. (2015). Is the impairment in temporal allocation of visual attention in children with ADHD related to a developmental delay or a structural cognitive deficit? *Research in Developmental Disabilities*, *36*, 384–395. https://doi.org/10.1016/j.ridd.2014.10.014

Donnelly, N., Muhl-Richardson, A., Godwin, H. J., & Cave, K. R. (2019). Using eye movements to understand how security screeners search for threats in x-ray baggage. *Vision*, *3*(2), 24. https://doi.org/10.3390/vision3020024

Dugué, L., Beck, A.-A., Marque, P., & VanRullen, R. (2019). Contribution of FEF to attentional periodicity during visual search: A TMS study. *eNeuro*, *6*(3), eneuro.0357-18.2019. https://doi.org/10.1523/eneuro.0357-18.2019

Eckstein, M. P. (2011). Visual search: A retrospective. *Journal of Vision*, *11*(5), Article e14. https://doi.org/10.1167/11.5.14

Ellison, A., Ball, K. L., Moseley, P., Dowsett, J., Smith, D. T., Weis, S., & Lane, A. R. (2014). Functional interaction between right parietal and bilateral frontal cortices during visual search tasks revealed using functional magnetic imaging and transcranial direct current stimulation. *PLOS ONE*, *9*(4), Article e93767. https://doi.org/10.1371/journal.pone.0093767

Ellison, A., Lane, A. R., & Schenk, T. (2007). The interaction of brain regions during visual search processing as revealed by transcranial magnetic stimulation. *Cerebral Cortex*, *17*(11), 2579–2584. https://doi.org/10.1093/cercor/bhl165

Emerson, R. L., García-Molina, A., López Carballo, J., García Fernández, J., Aparicio- López, C., Novo, J., Sánchez-Carrión, R., Enseñat-Cantallops, A., & Peña- Casanova, J. (2019). Visual search in unilateral spatial neglect: The effects of distractors on a dynamic visual search task. *Applied Neuropsychology: Adult*, *26*(5), 401–410. https://doi.org/10.1080/23279095.2018.1434522

Epstein, R. A., & Baker, C. I. (2019). Scene Perception in the Human Brain. *Annual Review of Vision Science*, *5*(1), 373–397. https://doi.org/10.1146/annurev-vision- 091718-014809

Eraslan Boz, H., Koçoğlu, K., Akkoyun, M., Tüfekci, I. Y., Ekin, M., & Akdal, G. (2023). Visual search in Alzheimer's disease and amnestic mild cognitive impairment: An eye-tracking study. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association*, *20*(2), 759-768. https://doi.org/10.1002/alz.13478

Eriksen, C. W., & Yeh, Y.-Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance*, *11*(5), 583–597. https://doi.org/10.1037/0096-1523.11.5.583

Evans, K. K., Horowitz, T. S., Howe, P., Pedersini, R., Reijnen, E., Pinto, Y., Kuzmova, Y., & Wolfe, J. M. (2011). Visual attention. *WIREs Cognitive Science*, *2*(5), 503–514. https://doi.org/10.1002/wcs.127

Faieq, A. K., & Mijwil, M. M. (2022). The utilisation of machine learning techniques in the diagnosis of breast cancer. *In Proceedings of the 5th International Conference on Data Science and Applications (ICONDATA'22)* (pp. 7–11). https://doi.org/10.24203/ajcis.v9i4.6765

Federici, A., Bennett, C. R., Bauer, C. M., Manley, C. E., Ricciardi, E., Bottari, D., & Merabet, L. B. (2023). Altered neural oscillations underlying visuospatial processing in cerebral visual impairment. *Brain Communications*, *5*(5), Article efcad232. https://doi.org/10.1093/braincomms/fcad232

Fellrath, J., Blanche-Durbec, V., Schnider, A., Jacquemoud, A.-S., & Ptak, R. (2012). Visual search in spatial neglect studied with a preview paradigm. *Frontiers in Human Neuroscience*, Article e6. http://www.frontiersin.org/articles/10.3389/fnhum.2012.00093

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological Bulletin*, *134*(5), 662–676. https://doi.org/10.1037/0033-2909.134.5.662

Gaspelin, N., Leonard, C. J., & Luck, S. J. (2017). Suppression of overt attentional capture by salient-but-irrelevant color singletons. *Attention, Perception, & Psychophysics, 79*(1), 45–62 https://doi.org/10.3758/s13414-016-1209-1

Ghose, T., Mathur, A., & Majumdar, R. (2018). Study of visual search in 3D space using virtual reality (VR). *Journal of Vision, 18*(10), Article e286. https://doi.org/10.1167/18.10.286

Gillebert, C. R., & Humphreys, G. W. (2010). The decomposition of visual binding over time: Neuropsychological evidence from illusory conjunctions after posterior parietal damage. *Visual Cognition*, *18*(7), 954–980. https://doi.org/10.1080/13506280903356764

Gliga, T., Bedford, R., Charman, T., Johnson, M. H., & BASIS Team. (2015). Enhanced visual search in infancy predicts emerging autism symptoms. *Current Biology*, *25*(13), 1727–1730. https://doi.org/10.1016/j.cub.2015.05.011

Golarai, G., Grill-Spector, K., & Reiss, A. L. (2006). Autism and the development of face processing. *Clinical Neuroscience Research*, *6*(3), 145–160. https://doi.org/10.1016/j.cnr.2006.08.001

Greenberg, A. S., Rosen, M., Cutrone, E., & Behrmann, M. (2015). The effects of visual search efficiency on object-based attention. *Attention, Perception, & Psychophysics*, *77*(5), 1544–1557. https://doi.org/10.3758/s13414-015-0892-7

Guilbert, A., & Rochette, F. (2023). Visual search organization in a cancellation task in developmental dyslexia. *Cognitive Neuropsychology*, 40(3-4), 148-157. https://doi.org/10.1080/02643294.2023.2286026

Guo, J., Luo, X., Kong, Y., Li, B., Si, B., Jensen, O., Sun, L., & Song, Y. (2023a). The effects of first-dose methylphenidate on the neural signatures of visual selective attention in children with attention-deficit/hyperactivity disorder. *Biological Psychology*, *177*, Article e108481. https://doi.org/10.1016/j.biopsycho.2022.108481

Guo, J., Luo, X., Kong, Y., Li, B., Si, B., Sun, L., & Song, Y. (2023b). Abnormal reactivity of brain oscillations to visual search target in children with attention-deficit/hyperactivity disorder. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *8*(5),522–530. https://doi.org/10.1016/j.bpsc.2022.03.002

Gutschalk, A., & Dykstra, A. R. (2015). Auditory neglect and related disorders. In M. J. Aminoff, F. Boller, & D. F. Swaab (Eds.), *Handbook of Clinical Neurology* (Vol. 129, pp. 557–571). Elsevier. https://doi.org/10.1016/B978-0-444-62630-1.00031-7

Hadad, B.-S., & Yashar, A. (2022). Sensory perception in autism: What can we learn? *Annual Review of Vision Science*, *8*(1), 239–264. https://doi.org/10.1146/annurev-vision-093020-035217

Hamblin-Frohman, Z., Chang, S., Egeth, H., & Lleras, A. (2022). Eye movements reveal the contributions of early and late processes of enhancement and suppression to the guidance of visual search. *Attention, Perception, & Psychophysics, 84*(6), 1913–1924. https://doi.org/10.3758/s13414-022-02536-w

Hansen, C. H., & Hansen, R. D. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology*, *54*(6), 917–924. https://doi.org/10.1037/0022-3514.54.6.917

Hassan, M. M., & Mokhtar, H. M. O. (2019). Investigating autism etiology and heterogeneity by decision tree algorithm. *Informatics in Medicine Unlocked*, *16*, Article e100215. https://doi.org/10.1016/j.imu.2019.100215

Hazell, P. L., Carr, V. J., Lewin, T. J., Dewis, S. A., Heathcote, D. M., & Brucki, B. M. (1999). Effortful and automatic information processing in boys with ADHD and specific learning disorders. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *40*(2), 275–286. https://doi.org/10.1111/1469-7610.00441

Heilman, K., Valenstein, E., & Watson, R. (2000). Neglect and related disorders. *Seminars in Neurology*, *20*, 463–470. https://doi.org/10.1055/s-2000-13179

Hemström, J., Albonico, A., Djouab, S., & Barton, J. J. S. (2019). Visual search for complex objects: Set-size effects for faces, words and cars. *Vision Research*, *162*, 8–19. https://doi.org/10.1016/j.visres.2019.06.007

Hirota, T., & King, B. H. (2023). Autism spectrum disorder: A Review. *JAMA*, *329*(2), 157–168. https://doi.org/10.1001/jama.2022.23661

Hooge, I. T. C., Niehorster, D. C., Nyström, M., Andersson, R., & Hessels, R. S. (2022). Fixation classification: How to merge and select fixation candidates. *Behavior Research Methods, 54*(6), 2765–2776. https://doi.org/10.3758/s13428-021- 01723-1

Hoppe, D., & Rothkopf, C. A. (2019). Multi-step planning of eye movements in visual search. *Scientific Reports, 9*(1), Article e144. https://doi.org/10.1038/s41598-018-37536-0

Horstmann, G., Scharlau, I., & Ansorge, U. (2006). More efficient rejection of happy than of angry face distractors in visual search. *Psychonomic Bulletin & Review*, *13*(6), 1067–1073. https://doi.org/10.3758/BF03213927

Hsieh, P. J., Colas, J. T., & Kanwisher, N. (2011). Unconscious pop-out: Attentional capture by unseen feature singletons only when top-down attention is available. *Psychological Science*, *22*(9), 1220–1226. https://doi.org/10.1177/0956797611419302

Humphreys, G. W., Hodsoll, J., & Riddoch, M. J. (2009). Fractionating the binding process: Neuropsychological evidence from reversed search efficiencies. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(3), 627– 647. https://doi.org/10.1037/a0013705

Jassim, N., Baron-Cohen, S., & Suckling, J. (2021). Meta-analytic evidence of differential prefrontal and early sensory cortex activity during non-social sensory perception in autism. *Neuroscience & Biobehavioral Reviews*, *127*, 146–157. https://doi.org/10.1016/j.neubiorev.2021.04.014

Jin, H., Oxner, M., Corballis, P. M., & Hayward, W. G. (2022). Holistic face processing is influenced by non-conscious visual information. *British Journal of Psychology, 113*(1), 300–326. https://doi.org/10.1111/bjop.12521

Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science*, *12*(6), 1083–1096. https://doi.org/10.1111/j.1467-7687.2009.00855.x

Juth, P., Lundqvist, D., Karlsson, A., & Öhman, A. (2005). Looking for foes and friends: perceptual and emotional factors when finding a face in the crowd. *Emotion*, *5*(4), 379–395. https://doi.org/10.1037/1528-3542.5.4.379

Kaldy, Z., Giserman, I., Carter, A. S., & Blaser, E. (2016). The mechanisms underlying the ASD advantage in visual search. *Journal of Autism and Developmental Disorders*, *46*(5), 1513–1527. https://doi.org/10.1007/s10803-013-1957-x

Katsuki, F., & Constantinidis, C. (2014). Bottom-up and top-down attention: Different processes and overlapping neural systems. *The Neuroscientist: A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, *20*(5), 509–521. https://doi.org/10.1177/1073858413514136

Kavšek, M., Heil, M., & Granrud, C. E. (2022). Holistic face processing in 4- and 7- month-old infants. *Infancy: The Official Journal of the International Society on Infant Studies*, *27*(6), 1052–1067. https://doi.org/10.1111/infa.12504

Kazanovich, Y., & Borisyuk, R. (2017). Reaction times in visual search can be explained by a simple model of neural synchronization. *Neural Networks*, *87*, 1–7. https://doi.org/10.1016/j.neunet.2016.12.003

Keehn, B., & Joseph, R. M. (2016). Slowed search in the context of unimpaired grouping in autism: Evidence from multiple conjunction search. *Autism Research: Official Journal of the International Society for Autism Research*, *9*(3), 333–339. https://doi.org/10.1002/aur.1534

Keehn, B., Kadlaskar, G., & Keehn, R. M. (2023). Elevated and accelerated: Locus coeruleus activity and visual search abilities in autistic children. *Cortex*, *169*, 118–129. https://doi.org/10.1016/j.cortex.2023.08.016

Kershner, A. M., & Hollingworth, A. (2022). Real-world object categories and scene contexts conjointly structure statistical learning for the guidance of visual search. *Attention, Perception, & Psychophysics*, *84*(4), 1304–1316. https://doi.org/10.3758/s13414-022-02475-6

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing: An ERP study. *Biological Psychology*, *80*(1), 75–83. https://doi.org/10.1016/j.biopsycho.2008.03.004

Krakowski, C.-S., Borst, G., Pineau, A., Houdé, O., & Poirel, N. (2015). You can detect the trees as well as the forest when adding the leaves: Evidence from visual search tasks containing three-level hierarchical stimuli. *Acta Psychologica*, *157*, 131–143. https://doi.org/10.1016/j.actpsy.2015.03.001

Kristjánsson, Á., Ingvarsdöttir, Á., & Teitsdöttir, U. D. (2008). Object- and feature-based priming in visual search. *Psychonomic Bulletin & Review*, *15*(2), 378–384. https://doi.org/10.3758/PBR.15.2.378

Laasonen, M., Salomaa, J., Cousineau, D., Leppämäki, S., Tani, P., Hokkanen, L., & Dye, M. (2012). Project DyAdd: Visual attention in adult dyslexia and ADHD. *Brain and Cognition*, *80*(3), 311–327. https://doi.org/10.1016/j.bandc.2012.08.002

Leonard, C. J., & Egeth, H. E. (2008). Attentional guidance in singleton search: An examination of top-down, bottom-up, and intertrial factors. *Visual Cognition*, *16*(8), 1078–1091. https://doi.org/10.1080/13506280701580698

Leopold, D. A., & Rhodes, G. (2010). A comparative view of face perception. *Journal of Comparative Psychology, 124*(3), 233–251. https://doi.org/10.1037/a0019460

Li, F., Li, X., & Kou, H. (2023). Emotional recognition training enhances attention to emotional stimuli among male juvenile delinquents. *Psychology Research and Behavior Management*, *16*, 575–586. https://doi.org/10.2147/PRBM.S403512

Li, K., Kadohisa, M., Kusunoki, M., Duncan, J., Bundesen, C., & Ditlevsen, S. (2020). Distinguishing between parallel and serial processing in visual attention from neurobiological data. *Royal Society Open Science*, *7*(1), Article e191553. https://doi.org/10.1098/rsos.191553

Lian, X., Hong, W. C. H., Xu, X., Kimberly, K.-Z., & Wang, Z. (2023). The influence of picture book design on visual attention of children with autism: A pilot study. *International Journal of Developmental Disabilities*, *69*(6), 946–956. https://doi.org/10.1080/20473869.2022.2033590

Ligeza, T. S., Tymorek, A. D., & Wyczesany, M. (2017). Top-down and bottom-up competition in visual stimuli processing. *Acta Neurobiologiae Experimentalis, 77*(4), 305-316. https://doi.org/10.21307/ane-2017-063

Lipp, O. V., Price, S. M., & Tellegen, C. L. (2009a). Emotional faces in neutral crowds: Detecting displays of anger, happiness, and sadness on schematic and photographic images of faces. *Motivation and Emotion*, *33*(3), 249–260. https://doi.org/10.1007/s11031-009-9136-2

Lipp, O. V., Price, S. M., & Tellegen, C. L. (2009b). No effect of inversion on attentional and affective processing of facial expressions. *Emotion*, *9*(2), 248–259. https://doi.org/10.1037/a0014715

Llorens, R., & Noé, E. (2016). Through the eyes of neglect patients: A preliminary eye- tracking study of unilateral spatial neglect. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *28*(1), Article e8-9. https://doi.org/10.1176/appi.neuropsych.15060156

López Pérez, D., Kennedy, D. P., Tomalski, P., Bölte, S., D'Onofrio, B., & Falck-Ytter, T. (2019). Visual search performance does not relate to autistic traits in the general population. *Journal of Autism and Developmental Disorders*, *49*(6), 2624–2631. https://doi.org/10.1007/s10803-019-03907-3

Luck, S. J., & Ford, M. A. (1998). On the role of selective attention in visual perception. *Proceedings of the National Academy of Sciences*, *95*(3), 825–830. https://doi.org/10.1073/pnas.95.3.825

Luvizutto, G. J., Fogaroli, M. O., Theotonio, R. M., Moura Neto, E. D., Nunes, H. R. D. C., & Bazan, R. (2020). Norm scores of cancelation and bisection tests for unilateral spatial neglect: Data from a Brazilian population. *Clinics*, *75*, Article e1468. https://doi.org/10.6061/clinics/2019/e1468

Maccari, L., Pasini, A., Caroli, E., Rosa, C., Marotta, A., Martella, D., Fuentes, L. J., & Casagrande, M. (2014). Visual search and emotion: How children with autism spectrum disorders scan emotional scenes. *Journal of Autism and Developmental Disorders*, *44*(11), 2871–2881. https://doi.org/10.1007/s10803-014-2148-0

Marciano, H., Gal, E., Kimchi, R., Hedley, D., Goldfarb, Y., & Bonneh, Y. S. (2022). Visual detection and decoding skills of aerial photography by adults with autism spectrum disorder (ASD). *Journal of Autism and Developmental Disorders*, *52*(3), 1346–1360. https://doi.org/10.1007/s10803-021-05039-z

Martin, A., & Becker, S. I. (2018). How feature relationships influence attention and awareness: Evidence from eye movements and EEG. *Journal of Experimental Psychology: Human Perception and Performance, 44*(12),1865–1883.https://doi.org/10.1037/xhp0000574

Masi, A., DeMayo, M. M., Glozier, N., & Guastella, A. J. (2017). An overview of autism spectrum disorder, heterogeneity and treatment options. *Neuroscience Bulletin*, *33*(2), 183–193. https://doi.org/10.1007/s12264-017-0100-y

Mason, D. J., Humphreys, G. W., & Kent, L. (2004). Visual search, singleton capture, and the control of attentional set in ADHD. *Cognitive Neuropsychology*, *21*(6), 661–687. https://doi.org/10.1080/02643290342000267

Mason, D. J., Humphreys, G. W., & Kent, L. S. (2003). Exploring selective attention in ADHD: Visual search through space and time. *Journal of Child Psychology and Psychiatry*, *44*(8), 1158–1176. https://doi.org/10.1111/1469-7610.00204

Mayer, J. S., Bernhard, A., Fann, N., Boxhoorn, S., Hartman, C. A., Reif, A., & Freitag, C. M. (2021). Cognitive mechanisms underlying depressive disorders in ADHD: A systematic review. *Neuroscience & Biobehavioral Reviews*, *121*, 307–345. https://doi.org/10.1016/j.neubiorev.2020.12.018

McCants, C. W., Berggren, N., & Eimer, M. (2018). The guidance of visual search by shape features and shape configurations. *Journal of Experimental Psychology: Human Perception and Performance*, *44*(7), 1072–1085. https://doi.org/10.1037/xhp0000514

McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. *Psychonomic Bulletin & Review*, *16*(5), 778–797. https://doi.org/10.3758/PBR.16.5.778

McLoughlin, G., Albrecht, B., Banaschewski, T., Rothenberger, A., Brandeis, D., Asherson, P., & Kuntsi, J. (2010). Electrophysiological evidence for abnormal preparatory states and inhibitory processing in adult ADHD. *Behavioral and Brain Functions*, *6*, Article e66. https://doi.org/10.1186/1744-9081-6-66

Memari, A. H., Ghanouni, P., Shayestehfar, M., Ziaee, V., & Moshayedi, P. (2014). Effects of visual search vs. Auditory tasks on postural control in children with autism spectrum disorder. *Gait & Posture*, *39*(1), 229–234. https://doi.org/10.1016/j.gaitpost.2013.07.012

Meuter, R. F. I., & Lacherez, P. F. (2016). When and why threats go undetected: Impacts of event rate and shift length on threat detection accuracy during airport baggage screening. *Human Factors*, *58*(2), 218–228. https://doi.org/10.1177/0018720815616306

Michelini, G., Salmastyan, G., Vera, J. D., & Lenartowicz, A. (2022). Event-related brain oscillations in attention-deficit/hyperactivity disorder (ADHD): A systematic review and meta-analysis. *International Journal of Psychophysiology*, *174*, 29–42. https://doi.org/10.1016/j.ijpsycho.2022.01.014

Minio-Paluello, I., Porciello, G., Pascual-Leone, A., & Baron-Cohen, S. (2020). Face individual identity recognition: A potential endophenotype in autism. *Molecular Autism*, *11*(1), Article e81. https://doi.org/10.1186/s13229-020-00371-0

Molenberghs, P., & Sale, M. V. (2011). Testing for spatial neglect with line bisection and target cancellation: Are both tasks really unrelated? *PLoS ONE*, *6*(7), Article e23017. https://doi.org/10.1371/journal.pone.0023017

Moran, R., Zehetleitner, M., Liesefeld, H. R., Müller, H. J., & Usher, M. (2016). Serial vs. parallel models of attention in visual search: Accounting for benchmark RT- distributions. *Psychonomic Bulletin & Review*, *23*(5), 1300–1315. https://doi.org/10.3758/s13423-015-0978-1

Morris, A. P., Kritikos, A., Berberovic, N., Pisella, L., Chambers, C. D., & Mattingley, J.B. (2004). Prism adaptation and spatial attention: A study of visual search in normals and patients with unilateral neglect. *Cortex*, *40*(4), 703–721. https://doi.org/10.1016/S0010-9452(08)70166-7

Mottron, L., & Bzdok, D. (2020). Autism spectrum heterogeneity: Fact or artifact? *Molecular Psychiatry*, *25*(12), 3178–3185. https://doi.org/10.1038/s41380-020- 0748-y

Müller, H. J., & and Krummenacher, J. (2006). Visual search and selective attention. *Visual Cognition*, *14*(4–8), 389–410. https://doi.org/10.1080/13506280500527676

Mullane, J. C., & Klein, R. M. (2008). Literature review: Visual search by children with and without ADHD. *Journal of Attention Disorders*, *12*(1), 44–53. https://doi.org/10.1177/1087054707305116

Naderi, M., Pladere, T., Alksnis, R., & Krumina, G. (2023). Brain activity underlying visual search in depth when viewing volumetric multiplanar images. *Scientific Reports*, *13*(1), Article e7672. https://doi.org/10.1038/s41598-023-34758-9

Najemnik, J., & Geisler, W. S. (2005). Optimal eye movement strategies in visual search. *Nature, 434*(7031), 387–391. https://doi.org/10.1038/nature03390

Nakatani, K., Notoya, M., Sunahara, N., Takahashi, S., & Inoue, K. (2013). Horizontal visual search in a large field by patients with unilateral spatial neglect. *Journal of Clinical Neuroscience*, *20*(6), 837–841. https://doi.org/10.1016/j.jocn.2012.07.014

Nobre, A. C., Coull, J. T., Walsh, V., & Frith, C. D. (2003). Brain activations during visual search: Contributions of search efficiency versus feature binding. *NeuroImage*, *18*(1), 91–103. https://doi.org/10.1006/nimg.2002.1329

Nordfang, M., & Wolfe, J. M. (2014). Guided search for triple conjunctions. *Attention, Perception & Psychophysics*, *76*(6), 1535–1559. https://doi.org/10.3758/s13414-014-0715-2

Nowakowska, A., Clarke, A. D., & Hunt, A. R. (2017). Human visual search behaviour is far from ideal. *Proceedings of the Royal Society B: Biological Sciences, 284*(1849), Article e20162767. https://doi.org/10.1098/rspb.2016.2767

Nuthmann, A., & Clark, C. N. L. (2023). Pseudoneglect during object search in naturalistic scenes. *Experimental Brain Research*, *241*(9), 2345–2360. https://doi.org/10.1007/s00221-023-06679-6

Nuthmann, A., Clayden, A. C., & Fisher, R. B. (2021). The effect of target salience and size in visual search within naturalistic scenes under degraded vision. *Journal of Vision*, *21*(4), Article e2. https://doi.org/10.1167/jov.21.4.2

O'Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology. Human Perception and Performance*, *27*(3), 719–730. https://doi.org/10.1037//0096-1523.27.3.719

O'Riordan, M., & Plaisted, K. (2001). Enhanced discrimination in autism. *The Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology*, *54*(4), 961–979. https://doi.org/10.1080/713756000

Ohmatsu, S., Takamura, Y., Fujii, S., Tanaka, K., Morioka, S., & Kawashima, N. (2019). Visual search pattern during free viewing of horizontally flipped images in patients with unilateral spatial neglect. *Cortex*, *113*, 83–95. https://doi.org/10.1016/j.cortex.2018.11.029

Olk, B., Dinu, A., Zielinski, D. J., & Kopper, R. (2018). Measuring visual search and distraction in immersive virtual reality. *Royal Society Open Science*, *5*(5), Article e172331.https://doi.org/10.1098/rsos.172331

Ortega, R., López, V., Carrasco, X., Anllo-Vento, L., & Aboitiz, F. (2013). Exogenous orienting of visual-spatial attention in ADHD children. *Brain Research*, *1493*, 68–79. https://doi.org/10.1016/j.brainres.2012.11.036

Paladini, R. E., Wyss, P., Kaufmann, B. C., Urwyler, P., Nef, T., Cazzoli, D., Nyffeler, T., & Müri, R. M. (2019). Re-fixation and perseveration patterns in neglect patients during free visual exploration. *European Journal of Neuroscience*, *49*(10), 1244–1253. https://doi.org/10.1111/ejn.14309

Palmer, J., Verghese, P., & Pavel, M. (2000). The psychophysics of visual search. *Vision Research*, *40*(10), 1227–1268. https://doi.org/10.1016/S0042-6989(99)00244-8

Pan, Y., Ge, X., Ge, L., & Xu, J. (2021). Using eye-controlled highlighting techniques to support both serial and parallel processing in visual search. *Applied Ergonomics*, *97*, Article e103522. https://doi.org/10.1016/j.apergo.2021.103522

Pedrazzini, E., Fellrath, J., Thézé, R., & Ptak, R. (2016). Electrophysiological correlates of visual binding errors after bilateral parietal damage. *Neuroscience*, *337*, 98–106. https://doi.org/10.1016/j.neuroscience.2016.09.016

Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998). Enhanced visual search for a conjunctive target in autism: A research note. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *39*(5), 777–783. https://doi.org/10.1111/1469-7610.00376

Plate, R. C., Powell, T., Bedford, R., Smith, T. J., Bamezai, A., Wedderburn, Q., Broussard, A., Soesanto, N., Swetlitz, C., Waller, R., & Wagner, N. J. (2023). Social threat processing in adults and children: Faster orienting to, but shorter dwell time on, angry faces during visual search. *Developmental Science*, Article e13461. https://doi.org/10.1111/desc.13461

Privitera, C. M., Noah, S., Carney, T., Klein, S. A., Lenartowicz, A., Hinshaw, S. P., McCracken, J. T., Nigg, J. T., Karalunas, S. L., Reid, R. C., Oliva, M. T., Betts, S. S., & Simpson, G. V. (2024). Pupillary dilations in a Target/Distractor visual task paradigm and attention deficit hyperactivity disorder (ADHD). *Neuroscience Letters*, *818*, Article e137556. https://doi.org/10.1016/j.neulet.2023.137556

Quinlan, P. T. (2003). Visual feature integration theory: Past, present, and future. *Psychological Bulletin*, *129*(5), 643–673. https://doi.org/10.1037/0033-2909.129.5.643

Rao, R. P. N., Zelinsky, G. J., Hayhoe, M. M., & Ballard, D. H. (2002). Eye movements in iconic visual search. *Vision Research, 42*(11), 1447–1463.https://doi.org/10.1016/S0042-6989(02)00040-8

Ricci, R., Salatino, A., Garbarini, F., Ronga, I., Genero, R., Berti, A., & Neppi-Mòdona, M. (2016). Effects of attentional and cognitive variables on unilateral spatial neglect. *Neuropsychologia*, *92*, 158–166. https://doi.org/10.1016/j.neuropsychologia.2016.05.004

Richler, J. J., Cheung, O. S., & Gauthier, I. (2011). Holistic Processing Predicts Face Recognition. *Psychological Science*, *22*(4), 464–471. https://doi.org/10.1177/0956797611401753

Rizzolatti, G., & Berti, A. (1994). Neural mechanisms of spatial neglect. In I. Robertson & J. Marshall (Eds.), *Unilateral neglect: Clinical and experimental studies* (pp. 87–102). Psychology Press.

Roberts, K. L., Allen, H. A., Dent, K., & Humphreys, G. W. (2015). Visual search in depth: The neural correlates of segmenting a display into relevant and irrelevant three-dimensional regions. *NeuroImage*, *122*, 298–305. https://doi.org/10.1016/j.neuroimage.2015.07.052

Robertson, C. E., & Baron-Cohen, S. (2017). Sensory perception in autism. *Nature Reviews Neuroscience*, *18*(11), Article e11. https://doi.org/10.1038/nrn.2017.112

Robertson, L., Treisman, A., Friedman-Hill, S., & Grabowecky, M. (1997). The interaction of spatial and object pathways: Evidence from Balint's syndrome. *Journal of Cognitive Neuroscience*, *9*(3), 295–317. https://doi.org/10.1162/jocn.1997.9.3.295

Saito, A., Sato, W., & Yoshikawa, S. (2023). Sex differences in the rapid detection of neutral faces associated with emotional value. *Biology of Sex Differences*, *14*(1), Article e84. https://doi.org/10.1186/s13293-023-00567-y

Sarwar, A., & Emmady, P. D. (2023). Spatial Neglect. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK562184/

Sauter, M., Stefani, M., & Mack, W. (2020). Towards interactive search: Investigating visual search in a novel real-world paradigm. *Brain Sciences*, *10*(12), Article e927. https://doi.org/10.3390/brainsci10120927

Savage, R. A., Becker, S. I., & Lipp, O. V. (2016). Visual search for emotional expressions: Effect of stimulus set on anger and happiness superiority. *Cognition and Emotion*, *30*(4), 713–730. https://doi.org/10.1080/02699931.2015.1027663

Savage, R. A., & Lipp, O. V. (2015). The effect of face inversion on the detection of emotional faces in visual search. *Cognition and Emotion*, *29*(6), 972–991. https://doi.org/10.1080/02699931.2014.958981

Savage, R. A., Lipp, O. V., Craig, B. M., Becker, S. I., & Horstmann, G. (2013). In search of the emotional face: Anger versus happiness superiority in visual search. *Emotion*, *13*(4), 758–768. https://doi.org/10.1037/a0031970

Seernani, D., Damania, K., Ioannou, C., Penkalla, N., Hill, H., Foulsham, T., Kingstone, A., Anderson, N., Boccignone, G., Bender, S., Smyrnis, N., Biscaldi, M., Ebner- Priemer, U., & Klein, C. (2021). Visual search in ADHD, ASD and ASD + ADHD: Overlapping or dissociating disorders? *European Child & Adolescent Psychiatry*, *30*(4), 549–562. https://doi.org/10.1007/s00787-020-01535-2

Shalev, L., Humphreys, G. W., & Mevorach, C. (2005). Global processing of compound lettersin a patient with Balint's syndrome. *Cognitive Neuropsychology*, *22*(6), 737–751. https://doi.org/10.1080/02643290442000284

Silva, A. D., Oliveira, A. M., Viegas, R. G., & Teixeira, N. S. (2011). What changes in face processing with face inversion and with short presentation durations? *Proceedings of Fechner Day*, *27*(1), 397–400.

Skalski, S., Konaszewski, K., Pochwatko, G., Balas, R., & Surzykiewicz, J. (2021). Effects of hemoencephalographic biofeedback with virtual reality on selected aspects of attention in children with ADHD. *International Journal of Psychophysiology*, *170*, 59–66. https://doi.org/10.1016/j.ijpsycho.2021.10.001

Slater, J., Joober, R., Koborsy, B. L., Mitchell, S., Sahlas, E., & Palmer, C. (2022). Can electroencephalography (EEG) identify ADHD subtypes? A systematic review. *Neuroscience & Biobehavioral Reviews*, *139*, Article e104752. https://doi.org/10.1016/j.neubiorev.2022.104752

Spelke, E. S. (1990). Principles of object perception. *Cognitive Science*, *14*(1), 29–56. https://doi.org/10.1207/s15516709cog1401_3

Stein, N., Watson, T., Lappe, M., & Bremmer, F. (2024). Eye and head movements in visual search in the extended field of view. *Scientific Reports, 14*(1), Article e8907. https://doi.org/10.1038/s41598-024-59657-5

Talsma, D., Coe, B., Munoz, D. P., & Theeuwes, J. (2010). Brain structures involved in visual search in the presence and absence of color singletons. *Journal of Cognitive Neuroscience*, *22*(4), 761–774. https://doi.org/10.1162/jocn.2009.21223

Tanaka, J. W., & Farah, M. J. (1993). Parts and Wholes in Face Recognition. *The Quarterly Journal of Experimental Psychology Section A*, *46*(2), 225–245. https://doi.org/10.1080/14640749308401045

Tanaka, Y., Ishikawa, K., Oyama, T., & Okubo, M. (2023). Face inversion does not affect the reversed congruency effect of gaze. *Psychonomic Bulletin & Review*, *30*(3), 974–982. https://doi.org/10.3758/s13423-022-02208-8

Thornton, T. L., & Gilden, D. L. (2007). Parallel and serial processes in visual search. *Psychological Review*, *114*(1), 71–103. https://doi.org/10.1037/0033- 295X.114.1.71

Tian, Y., Chica, A. B., Xu, P., & Yao, D. (2011). Differential consequences of orienting attention in parallel and serial search: An ERP study. *Brain Research*, *1391*, 81–92. https://doi.org/10.1016/j.brainres.2011.03.062

Ting, D. S. J., Pollock, A., Dutton, G. N., Doubal, F. N., Ting, D. S. W., Thompson, M., & Dhillon, B. (2011). Visual neglect following stroke: Current concepts and future focus. *Survey of Ophthalmology*, *56*(2), 114–134. https://doi.org/10.1016/j.survophthal.2010.08.001

Torrado, J. C., Montoro, G., & Gómez, J. (2016). Easing the integration: A feasible indoor wayfinding system for cognitive impaired people. *Pervasive and Mobile Computing*, *31*, 137–146. https://doi.org/10.1016/j.pmcj.2016.02.003

Treisman, A. (1982). Perceptual grouping and attention in visual search for features and for objects. *Journal of Experimental Psychology: Human Perception and Performance*, *8*(2), 194–214. https://doi.org/10.1037/0096-1523.8.2.194

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review*, *95*(1), 15–48. https://doi.org/10.1037/0033-295X.95.1.15

Tsao, D. Y., & Livingstone, M. S. (2008). Mechanisms of face perception. *Annual Review of Neuroscience*, *31*, 411–437. https://doi.org/10.1146/annurev.neuro.30.051606.094238

Türkan, B. N., Amado, S., Ercan, E. S., & Perçinel, I. (2016). Comparison of change detection performance and visual search patterns among children with/without ADHD: Evidence from eye movements. *Research in Developmental Disabilities*, *49–50*, 205–215. https://doi.org/10.1016/j.ridd.2015.12.002

Ueda, M., Yuri, T., Ueno, K., Ishii, R., & Naito, Y. (2023). The neurophysiological features associated with unilateral spatial neglect recovery: A scoping review. *Brain Topography*, *36*(5), 631–643. https://doi.org/10.1007/s10548-023-00980-x

Vallar, G., & Bolognini, N. (2014). Unilateral spatial neglect. In A. C. (Kia) Nobre & S. Kastner (Eds.), *The Oxford handbook of attention* (p. 972–1027). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199675111.013.012

Vallar, G., & Calzolari, E. (2018). Unilateral spatial neglect after posterior parietal damage. In G . Vallar & H. B. Coslett (Eds.), *Handbook of clinical neurology* (Vol. 151, pp. 287–312). Elsevier. https://doi.org/10.1016/B978-0-444-63622-5.00014-0

Van der Stigchel, S., & Nijboer, T. C. W. (2017). Spatial attention and eye movements. In A. Postma & I. J. M. van der Ham (Eds.), *Neuropsychology of space* (pp. 159–196). Academic Press. https://doi.org/10.1016/B978-0-12-801638-1.00005-7

Van der Stigchel, S., Belopolsky, A. V., Peters, J. C., Wijnen, J. G., Meeter, M., & Theeuwes, J. (2009). The limits of top-down control of visual attention. *Acta Psychologica*, *132*(3), 201–212. https://doi.org/10.1016/j.actpsy.2009.07.001

Vangkilde, S., & Habekost, T. (2010). Finding Wally: Prism adaptation improves visual search in chronic neglect. *Neuropsychologia*, *48*(7), 1994–2004. https://doi.org/10.1016/j.neuropsychologia.2010.03.020

Vestner, T., Gray, K. L. H., & Cook, R. (2021). Visual search for facing and non-facing people: The effect of actor inversion. *Cognition*, *208*. Article e104550. https://doi.org/10.1016/j.cognition.2020.104550

Walshe, R. C., & Geisler, W. S. (2022). Efficient allocation of attentional sensitivity gain in visual cortex reduces foveal sensitivity in visual search. *Current Biology*, *32*(1), 26-36.e6. https://doi.org/10.1016/j.cub.2021.10.011

Wang, S., Xu, J., Jiang, M., Zhao, Q., Hurlemann, R., & Adolphs, R. (2014). Autism spectrum disorder, but not amygdala lesions, impairs social attention in visual search. *Neuropsychologia*, *63*, 259–274. https://doi.org/10.1016/j.neuropsychologia.2014.09.002

Wilkinson, D., Ko, P., Milberg, W., & McGlinchey, R. (2008). Impaired search for orientation but not color in hemi-spatial neglect. *Cortex*, *44*(1), 68–78. https://doi.org/10.1016/j.cortex.2005.10.001

Williams, M., Moss, S., Bradshaw, J. L., & Mattingley, J. (2005). Look at me, I'm smiling: Visual search for threatening and nonthreatening facial expressions. *Visual Cognition*, *12*, 29–50. https://doi.org/10.1080/13506280444000193

Wolfe, J., Cain, M., Ehinger, K. & Drew, T. (2015). Guided Search 5.0: Meeting the challenge of hybrid search and multiple-target foraging. *Journal of Vision 15*(12), Article e1106. https://doi.org/10.1167/15.12.1106.

Wolfe, J., & Horowitz, T. (2008). Visual search. *Scholarpedia*, *3*, Article e3325. https://doi.org/10.4249/scholarpedia.3325

Wolfe, J. M. (1994). Guided Search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review*, *1*(2), 202–238. https://doi.org/10.3758/BF03200774

Wolfe, J. M. (1998). Visual search. In *Attention* (pp. 13–73). Psychology Press/Erlbaum (UK) Taylor & Francis.

Wolfe, J. M. (2007). Guided Search 4.0: Current progress with a model of visual search. In *Integrated models of cognitive systems* (pp. 99–119). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195189193.003.0008

Wolfe, J. M. (2010). Visual search. *Current Biology*, *20*(8), R346–R349. https://doi.org/10.1016/j.cub.2010.02.016

Wolfe, J. M. (2020). Visual search: How do we find what we are looking for? *Annual Review of Vision Science*, *6*, 539–562. https://doi.org/10.1146/annurev-vision- 091718-015048

Wolfe, J. M. (2021). Guided Search 6.0: An updated model of visual search. *Psychonomic Bulletin & Review*, *28*(4), 1060–1092. https://doi.org/10.3758/s13423-020-01859-9

Wolfe, J.M., & Gancarz, G. (1997). Guided Search 3.0. In Lakshminarayanan, V. (Eds) *Basic and clinical applications of vision science. Documenta ophthalmologica proceedings series*, (Vol 60, pp 189-192). Springer. https://doi.org/10.1007/978-94-011-5698-1_30

Wolfe, J. M., & Horowitz, T. S. (2017). Five factors that guide attention in visual search. *Nature Human Behaviour*, *1*(3), 0058. https://doi.org/10.1038/s41562-017-0058

Wolfe, J. M., Alvarez, G. A., Rosenholtz, R., Kuzmova, Y. I., & Sherman, A. M. (2011). Visual search for arbitrary objects in real scenes. *Attention, Perception, & Psychophysics*, *73*(6), 1650–1671. https://doi.org/10.3758/s13414-011-0153-3

Wolfe, J. M., Cave, K. R., & Franzel, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology. Human Perception and Performance*, *15*(3), 419–433. https://doi.org/10.1037//0096-1523.15.3.419

Wolfe, J. M., Palmer, E. M., & Horowitz, T. S. (2010). Reaction time distributions constrain models of visual search. *Vision Research*, *50*(14), 1304–1311. https://doi.org/10.1016/j.visres.2009.11.002

Wu, C. C., & Wolfe, J. M. (2022). The functional visual field(s) in simple visual search. *Vision Research*, *190*, Article e107965. https://doi.org/10.1016/j.visres.2021.107965

Zelinsky, G. J. (2008). A theory of eye movements during target acquisition. *Psychological Review, 115*(4), 787–835 https://doi.org/10.1037/a0013118

Zhou, R., Xie, X., Wang, J., Ma, B., & Hao, X. (2023). Why do children with autism spectrum disorder have abnormal visual perception? *Frontiers in Psychiatry*, *14*, Article e1087122. http://www.frontiersin.org/articles/10.3389/fpsyt.2023.1087122

Zhou, Y., & Yu, Y. (2021). Human visual search follows a suboptimal Bayesian strategy revealed by a spatiotemporal computational model and experiment. *Communications Biology, 4*(1), Article e34 https://doi.org/10.1038/s42003-020-01485-0