

Eye-tracking in behavioural sciences: a bibliometric analysis on research trends between 2015 - 2024

Hafidah Umar ^{1,2*} and Faiz Mustafar ^{1,2}

¹ Department of Neurosciences, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia.

² Brain and Behaviour Cluster, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia.

* Correspondence: hafidah_umar@usm.my; Tel.: +609-767 6438

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ABSTRACT: Eye-tracking technology is one of the fundamental tools in scientific research. Eye-tracking data can provide detailed insights into visual attention, perception, and other cognitive processes. This bibliometric analysis aims to systematically review the state-of-the-art of eye-tracking studies in the behavioural sciences, identify emerging research trends and thematic areas, and uncover future research directions. A comprehensive analysis was conducted using the SCOPUS database. The search strategy included keywords related to eye-tracking. The retrieved articles were analysed for publication trends, co-authorship networks, keyword co-occurrences, and thematic evolution over time. The analysis identified 5,825 relevant articles published between 2015 and 2024. The state-of-the-art of this area of study in behavioural sciences reveals a substantial increase in publications over the past decade. Research trends and thematic analysis highlight seven key areas of study, in particular: (1) driving behaviour; (2) social cognition; (3) cognitive ageing; (4) language processing; (5) visual cognition; (6) cognitive processes; and (7) electroencephalography (EEG). For future work, the analysis suggests promising research avenues, including the application of eye-tracking in virtual reality environments, longitudinal studies of attentional development, and interdisciplinary approaches combining eye-tracking with machine learning techniques. This study provides a comprehensive overview of the current landscape of eye-tracking research in behavioural sciences. The findings emphasise the versatility of eye-tracking as a methodological tool and highlight key areas for future investigation. By identifying emerging trends and suggesting new research directions, this study contributes to the ongoing development of eye-tracking methodologies in behavioural research.

Keywords: Eye-tracking; Behavioural sciences; Bibliometric analysis; Research trends; Thematic areas

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1.0 INTRODUCTION

Eye-tracking is a widely used research tool in the field of behavioural sciences. It helps us understand the cognitive and behavioural aspects of vision. Eye-tracking researchers are mainly interested in examining the point of gaze by tracking and measuring eye movements. This technology provides valuable insights into how individuals process visual information, make decisions, and respond to stimuli, which ensures a deeper understanding of attention, perception, and other cognitive processes ([Chen et al., 2023](#); [Masson et al., 2024](#); [Sahan et al., 2024](#)). Additionally, eye-tracking can be integrated with other physiological measures, such as electroencephalography (EEG), to study the neural correlates of visual and cognitive activities, further enriching the field's understanding of human behaviour and brain function ([Keskin et al., 2020](#); [Scharinger et al., 2020](#)).

An eye-tracker can also measure pupillary response (i.e., pupil constriction, pupil dilation). Pupil size can infer psychological and physiological states, such as cognitive load, emotional arousal, and attentional processes ([Mattavelli et al., 2022](#); [Purcell et al., 2023](#)). The pupillary light reflex, for instance, provides insights into the functioning of the autonomic nervous system. When light enters the eyes, the pupils constrict automatically. The autonomic nervous system governs this reaction and offers immediate insights into the functionality of the brain's pathways responsible for vision and autonomic regulation ([Anstis, 2018](#)).

Furthermore, changes in pupil diameter can indicate the intensity of cognitive processing or the presence of emotional stimuli. By analysing pupillary responses alongside eye movements, researchers can gain a comprehensive understanding of the interplay between cognitive functions and emotional states ([Karch et al., 2019](#)), thereby advancing our knowledge of the underlying mechanisms of human behaviour and perception.

Eye-tracking technology and methods began in the early 19th century. For most of the 20th century, recording and analysing eye-tracking data were difficult and expensive. The process of setting up the device was tedious and costly, and the analysis was also time-consuming ([Holmqvist et al., 2011](#)). However, contemporary eye-tracking systems employ video-based pupil-to-corneal reflection measurement technology, which is more practical, highly accurate, and user-friendly ([Carter & Luke, 2020](#); [Duchowski, 2007](#)). The advent of high-speed cameras and

sophisticated software has made the data collection process more efficient and the analysis more robust.

Eye-tracking research is experiencing rapid advancements with the emergence of interactive applications. Consequently, an increasing number of research fields are adopting eye-tracking methodologies. The process of recording eye movements has become more accurate, efficient, and accessible. Today, technological advances in hardware and software enable the collection of high-resolution data with minimal setup, broadening the scope of research applications across many new disciplines. Eye-tracking technology has been widely used in behavioural sciences, neuroscience, human-computer interaction, marketing, and economics ([Atkinson & Smithson, 2020](#); [Ratiu et al., 2022](#); [Yang et al., 2022](#)). The versatility and affordability of eye-tracking make it a valuable tool for studying visual attention, perception, and cognitive processes in diverse contexts. The capacity to monitor and analyse visual attention and gaze patterns provides profound insights across these domains.

Beyond academic contributions, understanding the evolution of eye-tracking research has broader implications for various stakeholders. Researchers can utilise the insights to refine experimental methodologies, optimise experimental designs, identify novel research directions, and encourage interdisciplinary collaborations. For practitioners in clinical settings, eye-tracking can be used for clinical diagnostics by providing objective measures for assessing cognitive and neurological disorders, for example, the detection of depression and anxiety-related attentional bias or screening for traumatic brain injury (TBI) and concussions. Professionals from industries, particularly in neuromarketing and user experience (UX) design, can use insights from eye-tracking to design and optimise advertisements and media, enhance user experience, conduct consumer behaviour analysis, or evaluate workplace ergonomics and productivity analysis.

To date, numerous studies have investigated the application of eye-tracking technology across a wide array of disciplines, providing valuable insights into cognitive processes and behavioural patterns. However, to the best of the authors' knowledge, only a few studies have examined the bibliometric analysis of eye-tracking studies in the behavioural sciences, especially those related to cognitive processes and behavioural patterns. Other bibliometric studies have examined

eye-tracking research in areas such as marketing, UX design, medicine, and education ([Atabay & Güzeller, 2021](#); [Ruppenthal & Schweers, 2024](#); [Salgado-Fernández et al., 2022](#); [Zammarchi & Conversano, 2021](#)).

To address this knowledge gap, this bibliometric study aims to provide a comprehensive analysis of scientific eye-tracking investigations within the behavioural sciences, an area in which no extensive landscape analysis has previously been conducted.

To achieve this, the study is structured around three key research questions. First, the state of the art in eye-tracking research (RQ1) is examined to establish a foundational understanding of developmental trends and publication outputs. This overview provides the context for exploring how research has evolved by highlighting the emerging thematic areas and research trends. Identifying these trends offers insight into aspects of eye-tracking research where the knowledge is expanding, and gaps persist (RQ2). Finally, recognising the knowledge gaps and thematic areas facilitates the identification of future directions for eye-tracking research (RQ3). All research questions were developed using a structured approach that maps the progression of eye-tracking research, offering a comprehensive perspective on its current state, ongoing trends, and potential future research efforts and advancements.

This study aims to enhance our understanding of how eye-tracking technology has been utilised and evolved within behavioural sciences by providing a systematic examination of the literature. It seeks to identify influential works, prominent researchers, and significant collaborations that have advanced the field. Additionally, the findings from this analysis will highlight innovative methodologies and interdisciplinary approaches that can inspire and inform future research directions, ultimately contributing to the continued growth and development of eye-tracking research in behavioural sciences.

2.0 METHODS

2.1 Data source and search strategy

The data source for this bibliometric review is the Scopus electronic database. Scopus is one of the major databases for citation analysis and journal ranking statistics. The decision to use the Scopus database to extract metadata aligns with the scientific literature coverage of the research area (i.e., behavioural sciences). Scopus also shows a higher number of document results and a less complicated filtering

operation to limit the document records. Scopus is also suitable because it is compatible with Harzing’s Publish or Perish and VOSviewer applications, used to conduct the analysis. The academic search of the Scopus database was performed on 21st July 2024.

To identify the relevant studies, the query was set searching <<eye-tracking OR “eye tracking” OR eyetracking OR “gaze tracking” OR eye-tracker* OR “eye tracker*” OR “eye movement*” OR eye-gaze OR “eye gaze” OR gaze* OR fixation*>> in the ‘Article title’ of the entire database. The query consists of different versions of spelling structure and phrases related to eye-tracking studies that scientific publications typically use. The workflow of the search strategies is shown in **Table 1**.

With four selected filters (i.e., Subject Area, Publication Year, Document Type, and Language), we reduced 118,027 documents to 5,825 (**Table 1**). The analysis covers only papers published in the behavioural sciences, including Psychology, Social Sciences, and Arts and Humanities, between 2015 and 2024. The number of records was also reduced by considering only the original research and excluding other types of publications, such as review papers, book chapters, conference papers, letters, books, and others. A manuscript with retracted and erratum status has also been excluded. Finally, we extracted only manuscripts written in English.

Table 1. Overview table of study screening and selection

Refine Results	Excluded Records
<p>Article title (eye-tracking OR “eye tracking” OR eyetracking OR “gaze tracking” OR eye-tracker* OR “eye tracker*” OR “eye movement*” OR eye-gaze OR “eye gaze” OR gaze* OR fixation*)</p> <p>Initial number of records = 118,027</p>	-
<p>Limit to: Subject area of behavioral sciences Remaining records = 15,010</p>	103,017
<p>Limit to: Publication Year of 2015 until 2024 Remaining records = 8,375</p>	6,635
<p>Limit to: Document type of Article Remaining records = 6,325</p>	2,050
<p>Limit to: Language of English Remaining records = 5,825</p>	500

2.2 Analytical tool

The main analysis tool used for science mapping or data visualisation of bibliometric data from Scopus is VOSviewer version 1.6.20 (released in October 2023). VOS stands for Visualisation of Similarities. VOSviewer is a computer program developed by researchers at the Centre for Science and Technology Studies (CWTS) at Leiden University that creates maps from network data and visualises large bibliometric networks ([Van Eck & Waltman, 2010](#)).

Apart from that, the analysis also used Harzing's Publish or Perish. This software is designed to retrieve and analyse academic citations, providing a wide range of citation metrics, such as the h-index, g-index, and the number of citations per paper ([Harzing, 2007](#)). Publish or Perish is a significant tool for assessing the impact and quality of academic publications. Using both VOSviewer and Publish or Perish enables comprehensive data visualisation and robust citation metrics, resulting in a thorough evaluation of the bibliometric data.

2.3 Data cleaning

The network visualisation map was generated using bibliographic data input in RIS format, extracted from the Scopus bibliographic database. Prior to analysis, data were cleaned to address inconsistencies, ensuring unbiased estimates and enhancing the reliability of decision-making. Faulty data entries were removed, and variations in singular and plural forms (e.g., fixation and fixations), hyphenated and non-hyphenated phrases (e.g., eye tracking and eye-tracking), synonymous terms (e.g., mental recall and memory), and acronym variants (e.g., electroencephalogram and EEG) were standardised. The data cleaning and preparation of a thesaurus file for VOSviewer analysis was essential to minimise measurement errors.

3.0 RESULTS

3.1 Research distribution analysis

3.1.1 Developmental trends from 1900 until 2024

An overview of the number of publications across time windows is important because it can be a strong indicator of the research area's development. The developmental trends from the earliest time offer a comprehensive historical overview of the development and evolution of interest in eye-tracking research. The analysis provides insights into the trajectory of academic inquiry, particularly regarding key periods of growth, stagnation, or shifts in research focus. This information is important for understanding how foundational theories and methodologies have

emerged and evolved, and it contextualises the current state of the field within its broader historical development.

Hence, articles published using similar keywords were identified to examine the overall developmental trends of eye-tracking research in the behavioural sciences, without limiting the publication year. The analysis of the search results yielded 10,601 entries. **Figure 1** shows the developmental trend of eye-tracking-related publications in the behavioural sciences from 1900 to 2024.

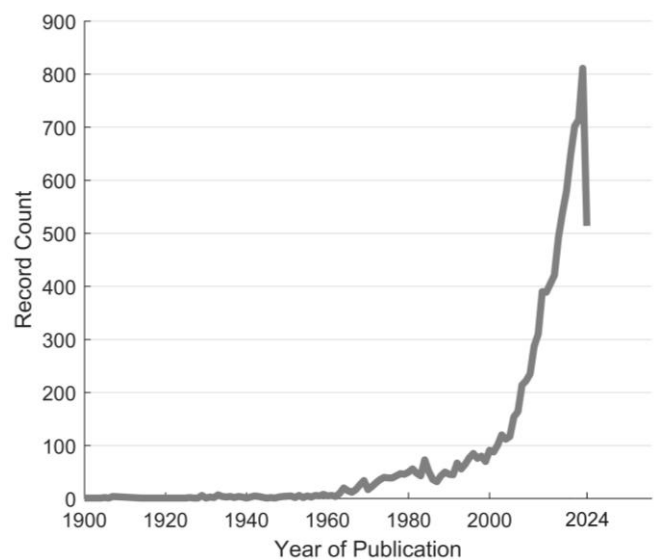


Figure 1. Annual publication counts published in Scopus from 1900 to 2024. The distribution of publication records is articles published in behavioral sciences.

In 1900, only one publication of an article entitled 'Visual perception during eye movement' was published in the 'Psychological Review.' The article highlights the challenges and perceptual fallacies that eye-tracking researchers encounter when measuring eye movements and fixations. The statistics show that the publication exceeded 100 in 2002, with 101 records. In 2018, the number of publications exceeded 500, reaching 539, and it steadily increased throughout the year. This developmental trend analysis gives us confidence in the rapid growth in the use of eye-tracking technology in the behavioural sciences. One reason for the rapid increase in the use of eye-tracking technology in research might be the emergence of more sophisticated, user-friendly systems that enable researchers to record multiple eye-tracking parameters with greater precision and accuracy

3.1.2 Analysis of publication outputs from 2015 until 2024

The present bibliometric study focused on the period from 2015 to 2024. Restricting the publication years allows an understanding of contemporary trends, including emerging interests and prominent topics in eye-tracking research, as well as rapid advancements in eye-tracking technology and its applications. Hence, the literature search yielded 5,825 articles from the Scopus database. **Figure 2** presents the number of publications on eye-tracking in the behavioural sciences between 2015 and 2024, including all articles published up to 21st July 2024.

The data clearly indicate an increasing interest in eye-tracking over time, and it is anticipated that this trend will continue due to the versatility of the method, which enables multidisciplinary collaboration and applications across various areas related to cognitive processes and behavioural patterns. Apart from that, analysing the developmental trends in more recent data allows the identification of emerging themes, current research hotspots, and potential future directions within the field.

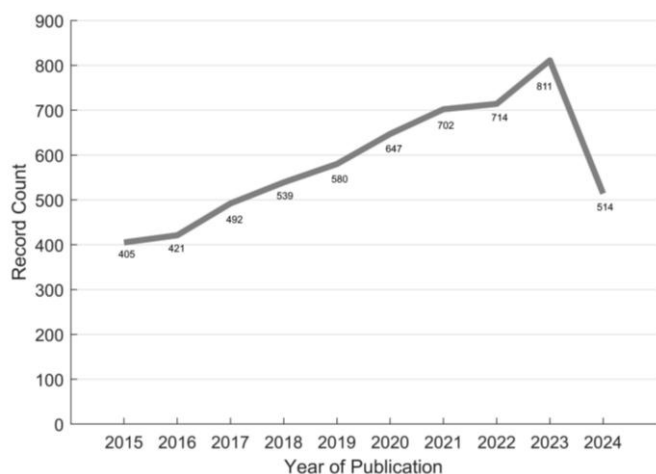


Figure 2. Publication counts from 2015 until 2024.

3.1.3 Countries

The bibliographic data showed that 59 countries are involved in eye-tracking research in the field of behavioural sciences. The United States has the largest contribution, with 1,426 published articles and 19,194 citations. The United Kingdom had the second-largest number of publications, with 895 papers and 13,331 citations, followed by Germany with 696 papers and 10,566 citations. **Table 2** lists the top 20 most influential countries. This distribution of papers from many

countries on different continents implies that eye-tracking technology has emerged as a global, reliable, extensive, and diverse research tool. The network visualisation of countries that published more than five articles is shown in **Figure 3**. An analysis of similarities shows that 40 countries are connected to one another.

Table 2. The twenty most productive countries of eye-tracking studies in behavioral sciences, 2015-2024.

Rank	Country	TP	TC	TC/TP
1	United States	1426	19194	13.46
2	United Kingdom	895	13331	14.89
3	Germany	696	10566	15.18
4	China	630	5052	8.02
5	Netherlands	344	6517	18.94
6	Canada	313	3761	12.02
7	Australia	275	3450	12.55
8	Italy	237	2800	11.81
9	France	235	2626	11.17
10	Spain	201	2642	13.14
11	Japan	186	1353	7.27
12	Sweden	156	2960	18.97
13	Switzerland	137	2126	15.52
14	Belgium	134	2044	15.25
15	Taiwan	120	1487	12.39
16	Finland	116	1526	13.16
17	Poland	112	1207	10.78
18	South Korea	108	1035	9.58
19	Israel	99	1040	10.51
20	Turkey	96	1048	10.92

TP = total number of publications; TC = total citations; TC/TP = average citations per publication.

3.1.4 Institutions

The citation analysis was used to identify the leading research institutions and organisations conducting eye-tracking studies in the behavioural sciences. The threshold was set to 5, the minimum number of publications an organisation must have, and we found that 70 organisations met it. The largest set of connected items consists of 46 items. **Table 3** lists the twenty institutions that contributed the most, and **Figure 4** shows the network visualisation of the most productive institutions.

3.1.5 Co-authorship analysis

Co-authorship analysis can help individual researchers identify opportunities for collaboration and provide information on the research network, research topic, and school of thought. Based on the retrieved data, 15,577 authors contributed to the 5,825 articles retrieved from the eye-tracking study in behavioural

sciences. It is estimated that the average number of authors per article is 2.67. Forty-one authors wrote 10 or more articles, and 261 authors (1.88%) wrote five or more articles.

Table 4 lists the top twenty most productive authors. The data visualisation map is based on the association strength of 261 authors who have published at least 5 eye-tracking articles in the behavioural sciences. The analysis showed that only 62 authors are connected or form a network. Hence, the network visualisation displayed in **Figure 5** is constructed from the connections among 62 authors.

3.1.6 Analysis of journals

Eye-tracking studies have become increasingly prominent in the field of behavioural sciences, providing invaluable insights into cognitive processes, behavioural patterns, and physiological responses. A bibliometric analysis of journals is essential to understand the landscape of research dissemination and impact in this area. This study utilises citation analysis to identify and evaluate the leading journals contributing to eye-tracking research within the behavioural sciences.

Table 5 presents the top 20 journals, ranked by citation metrics, that shape the discourse in this field of study. Furthermore, **Figure 6** illustrates a network visualisation comprising 102 connections among journals with at least 10 documents on eye-tracking studies, showcasing the interconnections and influence patterns within the scholarly community. This analysis aims to map the academic terrain, elucidate the pivotal sources, and foster a deeper understanding of the research dynamics in this area, particularly in behavioural sciences.

4.0 DISCUSSION

4.1 Identifying research hotspots and trends: keyword co-occurrence analysis

The keywords with the strongest citation bursts and the highest co-occurrence frequencies indicate research hotspots in the field. **Table 6** presents the co-occurrence frequencies of keywords within each cluster, where a longer list of keywords indicates a more prominent research domain. **Figure 7** illustrates the keyword co-occurrence network of eye-tracking studies in behavioural sciences, with a minimum occurrence threshold of 50.

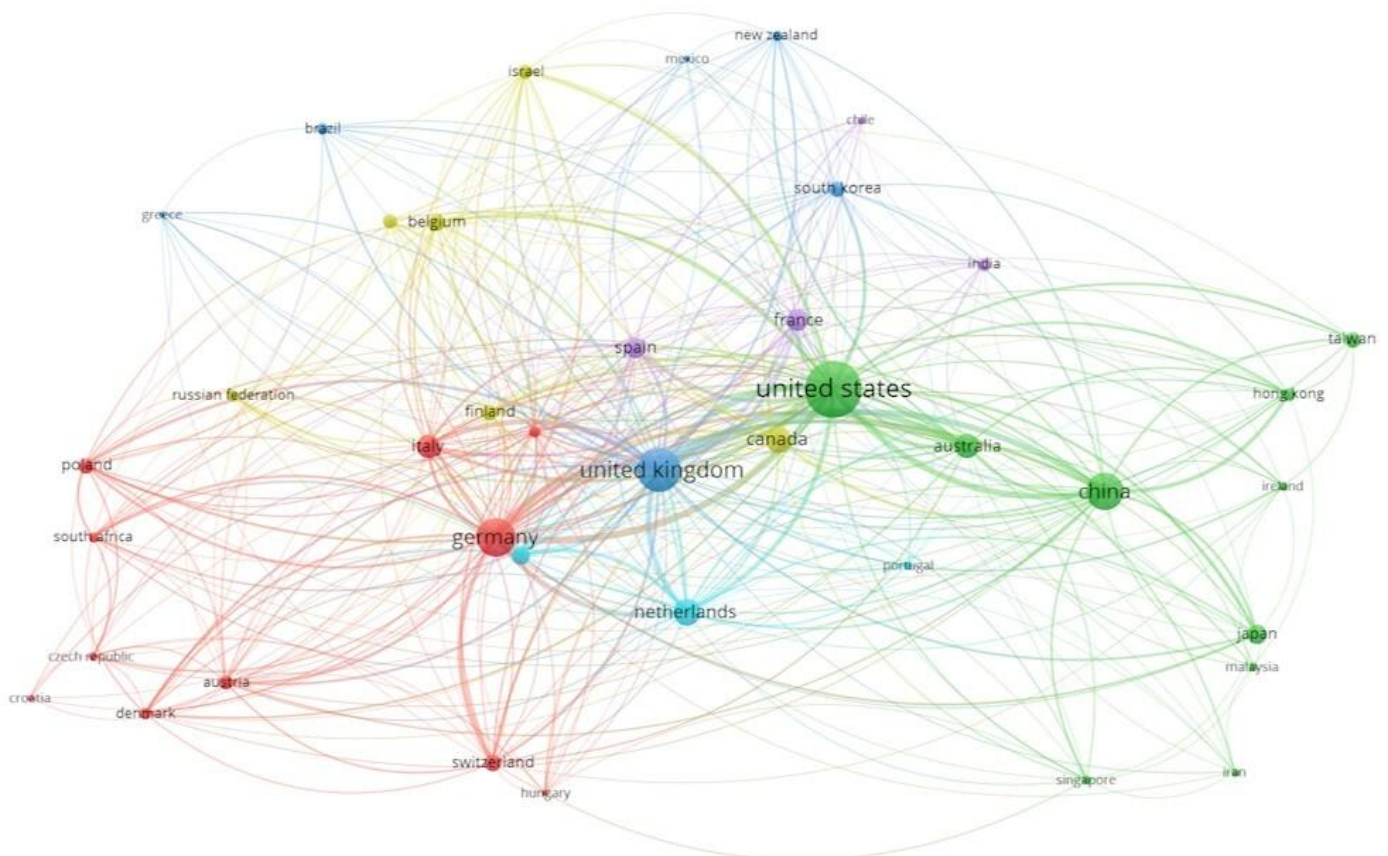


Figure 3. Distribution of main countries for eye-tracking study in behavioral sciences.

Table 3. The twenty most productive organizations of eye-tracking studies in behavioral sciences, 2015-2024.

Rank	Institution	Country	TP	TC	TC/TP
1	Utrecht University	Netherlands	53	1117	21.08
2	University of Turku	Finland	29	523	18.03
3	Lund University	Sweden	27	772	28.59
4	University of Aberdeen	United Kingdom	19	420	22.11
5	Ghent University	Belgium	18	490	27.22
6	University of East Anglia	United Kingdom	17	129	7.59
7	University of Tübingen	German	14	199	14.21
8	University of Nottingham	United Kingdom	14	188	13.43
9	Tianjin Normal University	China	14	78	5.57
10	University of California	United States	14	246	17.57
11	Uni of Chinese Academy of Science	China	14	108	7.71
12	Ewha Womans University	South Korea	12	20	1.67
13	University of Waterloo	Canada	12	250	20.83
14	Leibniz-Institut für Wissensmedien	Germany	11	203	18.45
15	University of Potsdam	Germany	11	303	27.55
16	University of Leicester	United Kingdom	11	83	7.55
17	Lancaster University	United Kingdom	11	160	14.55
18	University of Toronto	Canada	11	130	11.82
19	University of Southampton	United Kingdom	10	235	23.50
20	Max Planck Institute, Psycholinguistics	Netherlands	10	164	16.40

TP = total number of publications; TC = total citations; TC/TP = average citations per publication.

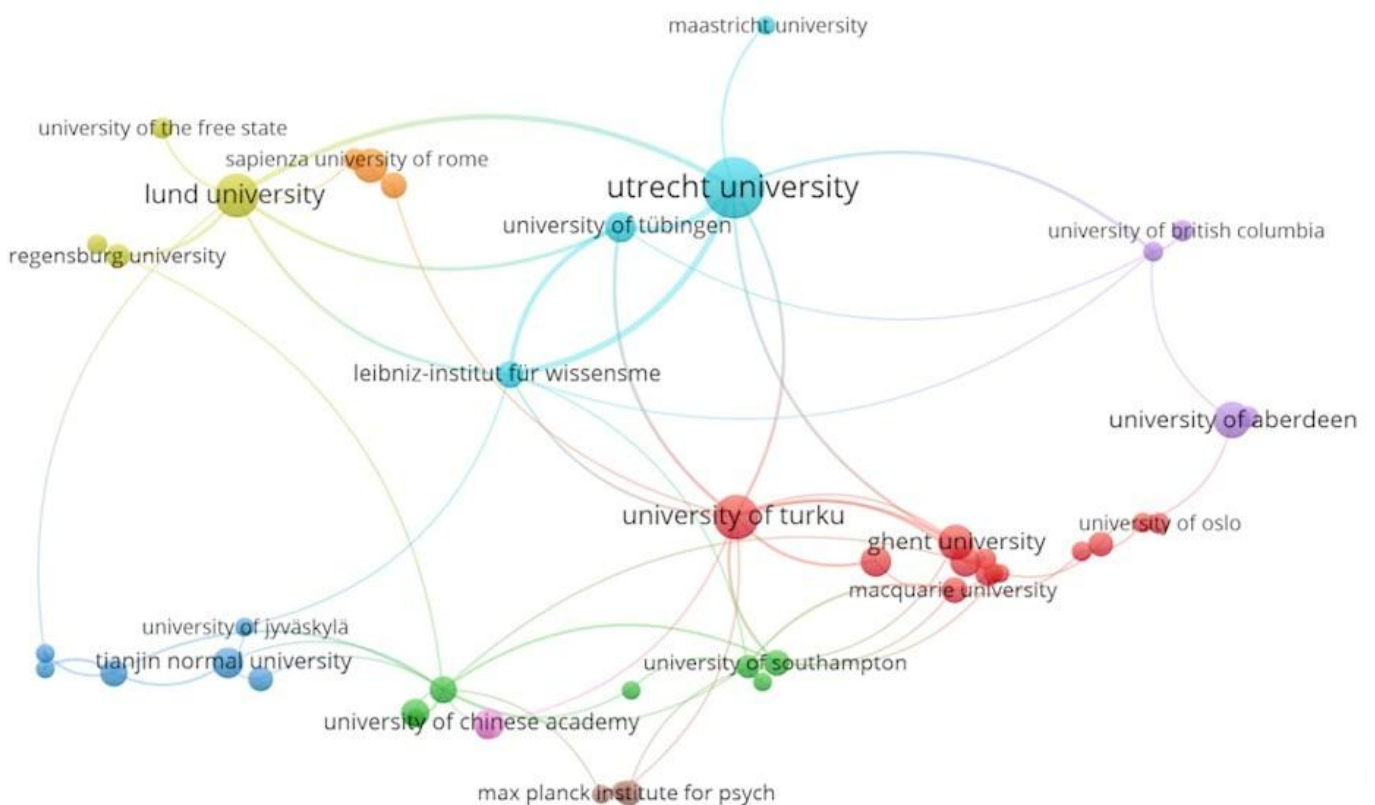


Figure 4. Network of main research organization collaboration of eye-tracking study in behavioral sciences.

Table 4. The twenty most productive authors of eye-tracking studies in behavioral sciences, 2015-2024.

Author	Affiliation	Country	TP	TC	TC/TP	h-index	G-index
Hooge, I.T.C.	Helmholtz Instituut, Utrecht	Netherlands	29	1028	35.45	15	29
Niehorster, D.C.	Lunds Universitet, Lund	Sweden	28	823	29.39	13	28
Hessels, R.S.	Helmholtz Instituut, Utrecht	Netherlands	27	983	36.41	15	27
Paterson, K.B.	University of Leicester	United Kingdom	27	298	11.04	10	16
Liversedge, S.P.	University of Central Lancashire, Preston	United Kingdom	23	446	19.39	10	21
Nyström, M.	Lunds Universitet, Lund	Sweden	22	549	24.95	12	22
Holmqvist, K.	Uniwersytet Mikołaja Kopernika w Toruniu, Torun, Kujawsko-Pomorskie	Poland	19	883	46.47	12	19
Hyönä, J.	Turun yliopisto, Turku	Finland	17	278	16.35	8	16
Jian, Y.C.	National Taiwan Normal University	Taiwan	17	252	14.82	10	15
Dong, W.	Beijing Normal University	China	16	261	16.31	10	16
Hietanen, J.K.	Tampere University	Finland	16	187	11.69	8	13
Li, X.	Institute of Psychology Chinese Academy of Sciences	China	15	204	13.60	6	14
Itier, R.J.	University of Waterloo	Canada	13	311	23.92	10	13
Kaakinen, J.K.	University of Turku	Finland	13	227	17.46	8	13
Dalmaso, M.	University of Padova	Italy	13	177	13.62	7	13
Staub, A.	University of Massachusetts	United States	12	463	38.58	11	12
Kingstone, A.	University of British Columbia	Canada	12	349	29.08	6	12
Jarodzka, H.	Open University of the Netherlands	Netherlands	12	338	28.17	8	12
McGowan, V.A.	University of Leicester	United Kingdom	12	197	16.42	9	12
Guerra, E.	Universidad de Chile	Chile	12	43	3.58	5	6

TP = total number of publications; TC = total citations; TC/TP = average citations per publication; h-index = document h-index; g-index = document g-index.

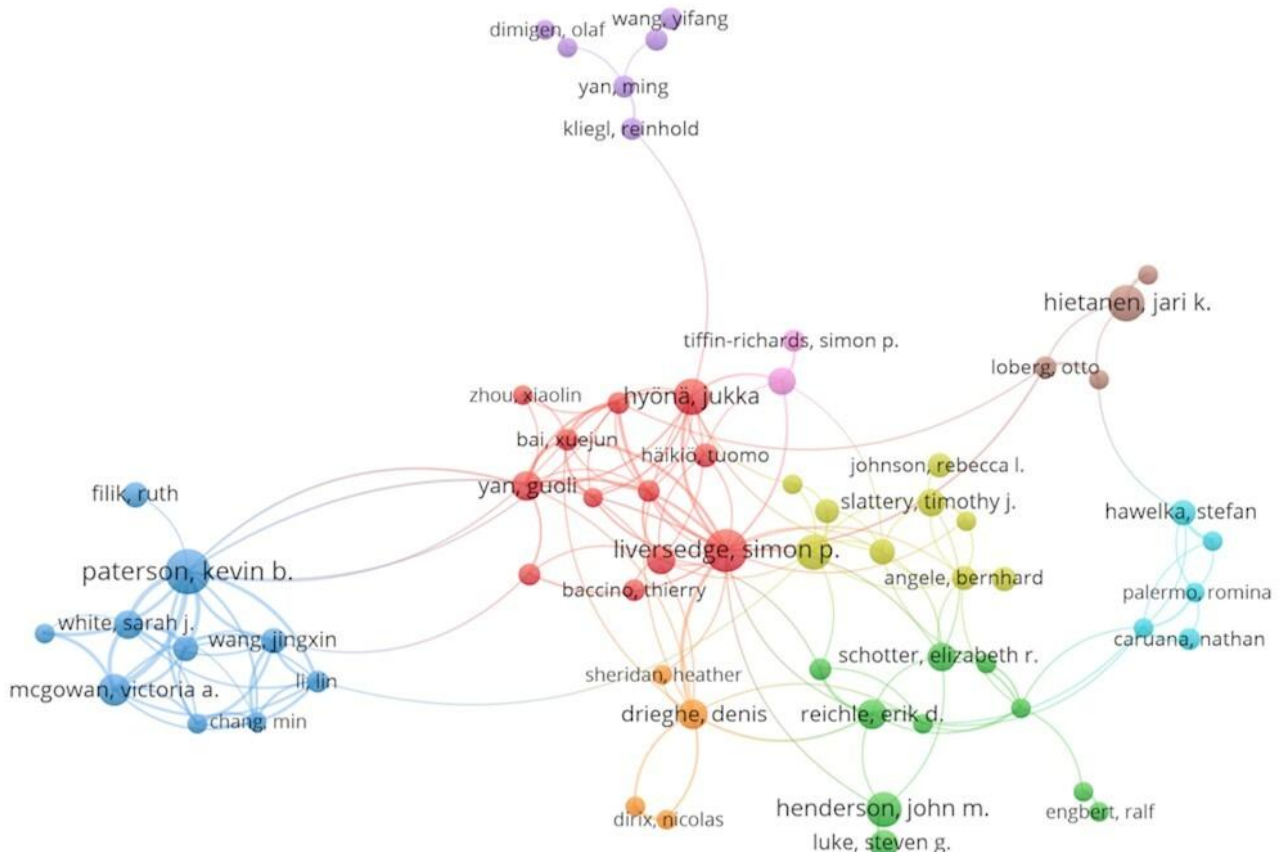


Figure 5. Network of productive author co-authorship for eye-tracking study in behavioral sciences.

Table 5. The twenty most productive publishing journals of eye-tracking studies in behavioral sciences, 2015-2024.

Rank	Journal	Publisher	Country	TP	TC	TC/TP	<i>h</i> -index
1	Frontiers in Psychology	Frontiers Media S.A.	Switzerland	360	3744	10.40	30
2	Behavior Research Methods	Springer Nature	United States	126	3335	26.47	31
3	Attention, Perception, and Psychophysics	Springer Nature	United States	103	928	9.01	16
4	Quarterly Journal of Experimental Psychology	SAGE	United Kingdom	95	956	10.06	17
5	Frontiers in Human Neuroscience	Frontiers Media S.A.	Switzerland	80	1264	15.80	21
6	Journal of Experimental Psychology: Learning Memory and Cognition	American Psychological Association	United States	63	920	14.60	18
7	Cognition	Elsevier	Amsterdam	62	1055	17.02	18
8	Sustainability (Switzerland)	Multidisciplinary Digital Publishing Institute (MDPI)	Switzerland	62	444	7.16	13
9	Journal of Experimental Psychology: Human Perception and Performance	American Psychological Association	United States	57	884	15.51	18
10	Psychonomic Bulletin and Review	Springer Nature	United States	57	724	12.70	17
11	Transportation Research Part F: Traffic Psychology and Behaviour	Elsevier	United Kingdom	46	833	18.11	17
12	Journal of Autism and Developmental Disorders	Springer Nature	United States	45	788	17.51	18
13	Visual Cognition	Taylor & Francis	United Kingdom	45	422	9.38	12
14	Computers in Human Behavior	Elsevier	United Kingdom	43	1506	35.02	26
15	Proceedings of the ACM on Human-Computer Interaction	Association for Computing Machinery	United States	43	278	6.47	10
16	International Journal of Human-Computer Interaction	Taylor & Francis	United States	41	471	11.49	13
17	Psychological Research	Springer Nature	Germany	40	416	10.40	12
18	Acta Psychologica	Elsevier	Amsterdam	40	361	9.03	11
19	Neuropsychologia	Elsevier	United Kingdom	38	334	8.79	12
20	Perception	SAGE	United Kingdom	37	276	7.46	9

TP = total number of publications; TC = total citations; TC/TP = average citations per publication; *h*-index = metric for productivity and impact.

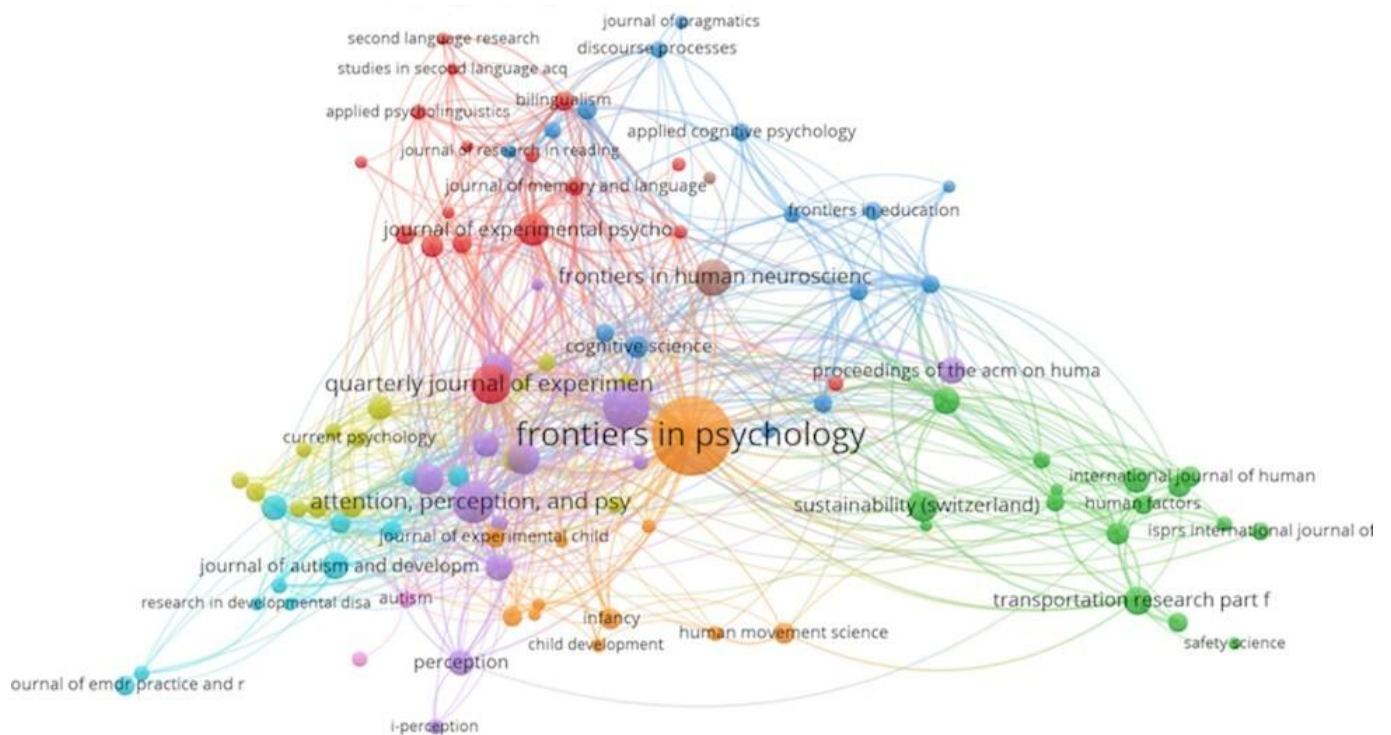


Figure 6. Network visualization map of co-citation analysis for journals that published articles of eye-tracking study in behavioral sciences.

Table 6. The primary themes consolidated into seven eye-tracking research clusters.

Cluster 1	Automobile driving, awareness, behavior, car driving, cognition, cognitive load, decision making, education, eye movement, eye-tracking, fixation, gaze behavior, head movement, human-computer interaction, information processing, learning, machine learning, motivation, problem-solving, pupil, task performance, virtual reality, visual attention.
Cluster 2	Autism, child, communication, cues, eye, eye fixation, eye gaze, face, facial recognition, gaze, infant, interpersonal communication, joint attention, pathophysiology, perception, social attention, social behavior, social cognition, social interaction, social perception.
Cluster 3	Age, aged, aging, executive function, memory, short-term memory, working memory, recall, mental recall, eye movement desensitization and reprocessing (EMDR), neuro-psychological test.
Cluster 4	Children, comprehension, eye movement measurement, individual differences, language, linguistics, oculography, pattern recognition, psycho-linguistics, reading, semantics, speech, speech perception.
Cluster 5	Attention, depth perception, orientation, photo stimulation, physiology, psychomotor performance, reaction time, saccadic eye movements, space perception, vision, visual perception, visual search.
Cluster 6	Anxiety, arousal, attentional bias, depression, emotion, facial expression, fear, happiness, visual stimulation.
Cluster 7	Brain, electro-encephalogram, electro-encephalography, evoked response.

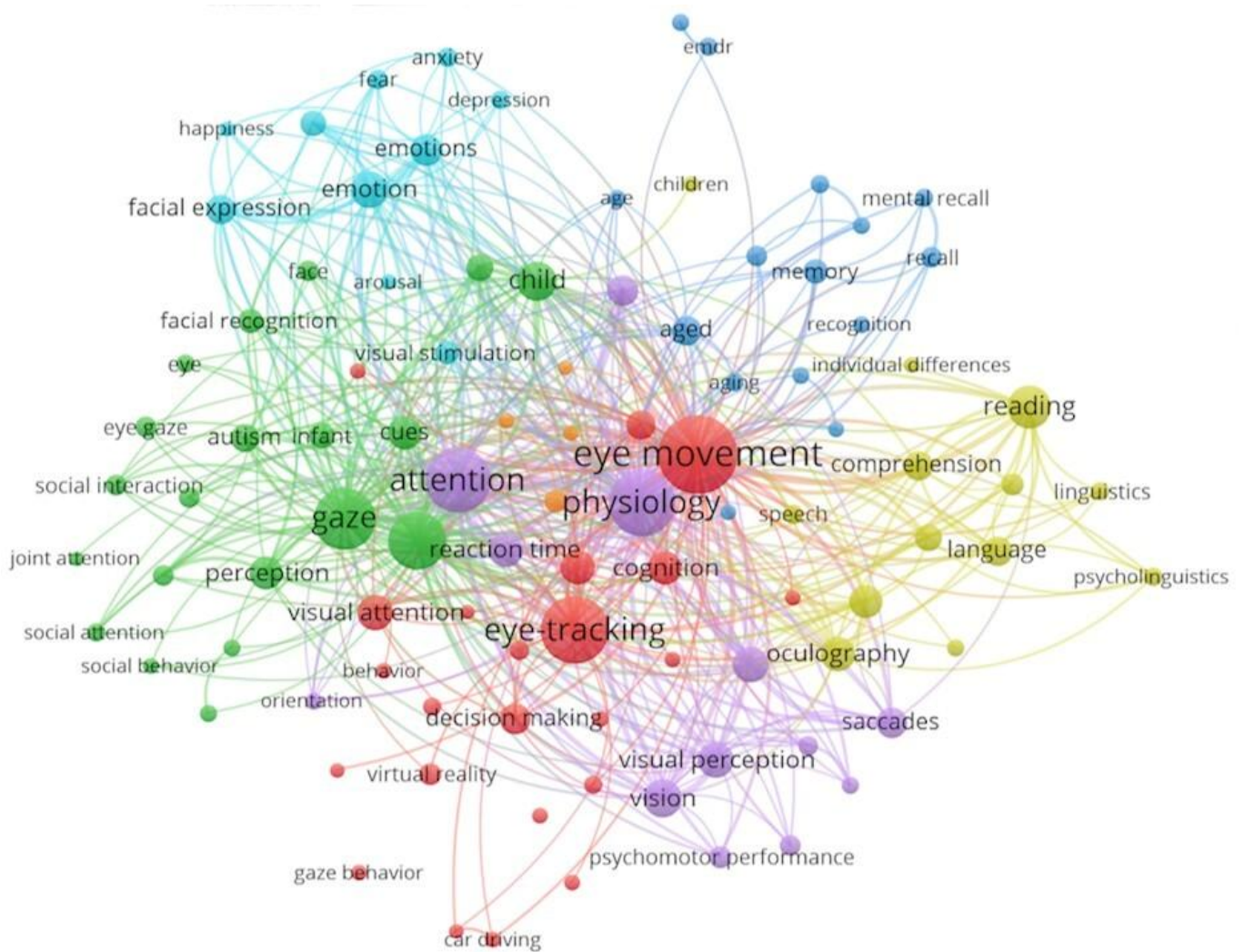


Figure 7. Co-occurrence network of all keywords for eye-tracking study in behavioral sciences.

Among the retrieved keywords, 98 met this criterion and formed seven distinct clusters (distinguished by red, green, blue, yellow, purple, turquoise, and orange) using similarity clustering in VOSviewer. To ensure relevant topic identification, general or unrelated keywords (e.g., ‘human’, ‘analysis of variance’, ‘case study’, ‘clinical trial’) were excluded. The exclusion of those keywords allows the analysis to focus on research hotspots and emerging trends in eye-tracking studies. The keywords within each cluster share conceptual similarities that reflect dominant research themes in behavioural sciences.

We find that the keywords in the same cluster share a common topic. Generally, most keywords in each cluster represent research hotspots within a single domain. The seven clusters that were identified are discussed in the following sections.

4.1.1 Cluster 1 (red colored)

The keywords in Cluster 1 encompass several topics related to eye-tracking applications in understanding driving behaviour through gaze data analysis and pupil response measures. Generally, gaze data enables researchers to monitor eye movements (e.g., gaze patterns, fixations, saccades), and it is important in understanding human visual abilities due to its close relationship with attentional processes, such as attentional bias or preference, response, demand, control, and other attentional mechanisms and experiences ([Broadbent et al., 2023](#); [Watling et al., 2022](#); [Zhang et al., 2022](#)). Pupil response can also serve as an objective and sensitive indicator of driving performance and mental workload, as it reflects cognitive demand through the physiological reflexes of pupil dilation and constriction ([Beatty, 1982](#); [Radhakrishnan et al., 2023](#)).

Other significant keywords in Cluster 1 include virtual reality (VR) and machine learning. Researchers often use VR in driving simulations to study driving behaviour and performance. VR enables detailed monitoring and recording of gaze behaviour and physiological responses in a controlled environment ([Portera & Bassani, 2024](#)). Furthermore, VR driving simulators provide a safe platform for learners to practice and experience a range of driving scenarios, enhancing their preparedness for real-world driving situations.

Machine learning (ML) is another crucial keyword identified in Cluster 1. ML is a rapidly evolving discipline that provides robust tools and techniques for analysing and enhancing driving behaviour. By leveraging large datasets and sophisticated algorithms, ML can uncover patterns and insights that are not easily detectable through manual and less data-intensive methods ([Bachurina et al., 2022](#); [Zemblys et al., 2018](#)). In driving behaviour research, ML facilitates the development of predictive models that can evaluate driver performance, identify risky behaviours, and propose interventions to improve safety and efficiency on the road ([Choe et al., 2023](#)). Additionally, eye-tracking technology offers detailed data on gaze patterns, fixation points, saccades, and pupil dilation. When combined with vehicle sensor data, such as speed, acceleration, braking patterns, and steering angles, these parameters can be used to understand drivers' attention and cognitive load comprehensively ([Shojaeizadeh et al., 2019](#)).

Driving is a complex activity that requires sustained attention, rapid decision-making, and efficient information processing. It involves continuously monitoring the environment, interpreting various stimuli, and responding to dynamic changes while controlling the vehicle. These processes place significant demands on cognitive resources, intrinsically linking driving performance to cognitive load. Cognitive load, which refers to the mental effort required to process information and perform tasks, can significantly impact driving performance ([Broadbent et al., 2023](#); [Fiočić et al., 2023](#)). Increased cognitive load can decrease attention, slow down decision-making, and reduce situational awareness. It can impair reaction times to hazards and decrease the efficiency of information processing, thus negatively affecting driving safety. Therefore, investigating and understanding cognitive load is essential for improving driving performance and reducing the risk of accidents.

4.1.2 Cluster 2 (green colored)

The keywords in cluster 2 revolve around the relevance of eye-tracking in understanding social cognition. Eye movements and pupil response data enable researchers to gain insights into the developmental processes in social communication by observing how adults and children engage in a social context, for example, their behaviour and interactions toward social cueing, social stress, emotions, mental states, and other instances ([Fogd et al., 2024](#); [Hou et al., 2024](#); [Kulke et al., 2024](#)).

One line of research in eye-tracking and social cognition focuses on understanding the mechanisms of social perception, including the processes involved in emotional recognition. By using facial expressions as a stimulus, researchers can track and analyse where participants focus their gaze, how long they fixate on a specific area of interest (AOI) within facial features, and how these patterns differ depending on the emotional facial expressions that are displayed ([Chung et al., 2023](#); [Fu et al., 2024](#); [Yüvrük et al., 2024](#)).

Other than that, eye-tracking is valuable for investigating aspects of social communication and perception, particularly in developmental and clinical settings. Previous research has demonstrated the relevance of eye-tracking in these areas. A study by Mo ([2024](#)) demonstrates that adults with high autistic traits exhibit slower visual attentional responses (longer latency to first fixation) to angry faces compared to those with low autistic traits, indicating decreased interest in threatening stimuli influenced by autistic traits and anxiety levels.

Similarly, research by Klin et al. ([2002](#)) revealed that young adults with autism exhibit reduced attention to the eye region compared to the age- and verbal IQ-matched controls. More attentional preference was allocated to the mouth, body, and object regions. Other clinical populations that have caught the interest of researchers are individuals with social anxiety disorder ([Lidle & Schmitz, 2024](#)), mood disorder ([Buhl et al., 2023](#)), attention deficit hyperactivity disorder (ADHD) ([Chacón-Candia et al., 2024](#)), language disorder ([Coloma et al., 2024](#); [Guerra et al., 2024](#)), eating disorder ([Meregalli et al., 2023](#)), alcohol disorder ([Pabst et al., 2023, 2024](#)), and many other conditions.

Additionally, joint attention is another keyword that emerged from cluster 2. A study by De Belen ([2023](#)) highlights the essential role of joint attention in early childhood development, particularly in social cognition. Joint attention is essential for social communication, as

it involves two individuals simultaneously focusing on the same object or event while being mutually aware of each other's attention.

The study confirms that children on the autism spectrum often face challenges with joint attention, which can be an early indicator of social communication difficulties. This body of work collectively emphasises the significance of eye-tracking as an effective method for investigating the complex dynamics of social cognition across diverse developmental and pathological contexts.

4.1.3 Cluster 3 (blue colored)

The keywords in cluster 3 centre on the overarching theme of cognitive ageing and memory processes, particularly in the context of neuropsychological assessment and therapeutic interventions. Central to this theme, eye-tracking methods offer valuable insights into cognitive processes, providing a non-invasive means to explore how these abilities are affected by ageing.

Eye-tracking is particularly useful in studying cognitive ageing, as it provides insights into how ageing affects attention, working memory, short-term memory, and executive function ([D'Innocenzo et al., 2022](#); [Naveh-Benjamin & Cowan, 2023](#)). For example, a study by [Fernandes et al. \(2024\)](#) found that older adults exhibited distinct viewing patterns, prioritising and focusing more on the areas where individuals in the scenes were directing their gaze. These findings indicate that older adults may be more sensitive to gaze cues than younger adults during free-viewing scenes. By tracking how the eyes navigate visual stimuli, researchers can identify subtle changes in attention and processing that accompany ageing, thereby contributing to more effective interventions and diagnostic tools for cognitive function and mental performance.

Another important value of eye-tracking is in assessing cognitive ageing, particularly in the context of memory recall. Older people often experience changes in memory function, which can be challenging to measure accurately using traditional methods alone. Eye-tracking offers a non-invasive way to gain insights into these changes by capturing detailed data on where and how long individuals focus their gaze during memory tasks. For example, [Mazloum-Farzhagi \(2023\)](#) conducted a study to understand how ageing affects eye movements and recognition memory, particularly in response to repeated exposure to visual stimuli. The researchers compared the performance of younger and

older adults on tasks in which participants were asked to recognise images of faces they had seen before.

The study found evidence that older adults exhibited different eye-movement patterns than younger adults when viewing repeated images. Older adults were less likely to focus on important features, which led them to score lower on recognition memory tasks. The study highlights older adults' challenges in processing and remembering visual information. These findings suggest that age-related changes in eye movement patterns may contribute to declines in recognition memory. These patterns can also reflect underlying changes in cognitive processes like encoding, retrieval, and attention.

By analysing these eye movements, researchers can better understand how ageing affects memory recall, which may further help in the earlier detection of cognitive decline and more targeted interventions. Furthermore, eye-tracking data can complement other neuropsychological assessments, providing a comprehensive picture of cognitive ageing and its impact on memory.

4.1.4 Cluster 4 (yellow colored)

The keywords in cluster 4 revolve around language comprehension and processing, particularly in children, using eye movement measurements and individual differences in linguistic abilities. Eye-tracking technology is a valuable tool for reading research, as it enables precise measurements of eye movement that reveal the cognitive mechanisms of how individuals process and comprehend text ([Angele & Duñabeitia, 2024](#); [Paulson et al., 2024](#)). By recording eye movements, researchers can analyse how individuals navigate text, identify patterns in reading behaviour, and understand the dynamics of visual attention during reading.

This method provides detailed data on fixations, saccades, and regressions, which is critical for understanding how readers decode and comprehend written language ([Moss et al., 2024](#)). For instance, studies have shown that variations in fixation duration can reveal differences in reading proficiency, working memory capacity, and the cognitive load experienced by readers ([Moss et al., 2024](#); [Yao et al., 2024](#)). Such insights are invaluable for developing targeted interventions to improve reading skills, especially for children learning to read.

Furthermore, eye-tracking allows researchers to investigate individual differences in linguistic abilities and reading fluency. Children of different ages, for example, exhibit different eye movement patterns, reflecting their developing cognitive and linguistic skills. Reading fluency is determined by the efficiency and processing speed of phonological decoding and orthographic coding, such as letter and word recognition and spelling patterns ([Hautala et al., 2024](#)). By examining these patterns, researchers can identify specific challenges faced by novice readers and tailor educational strategies to meet their needs.

Additionally, eye-tracking can be used to study the impact of linguistic variables, such as word frequency, sentence complexity, and grammatical rules (e.g., syntax, morphology, and agreement) on reading comprehension. The stability of eye-tracking metrics also allows investigation of how visual and linguistic information is integrated during reading, providing a comprehensive understanding of the reading process ([Lu et al., 2023](#); [Strandberg et al., 2023](#)). Consequently, numerous eye-tracking studies have established a robust framework for examining the intricate interplay between visual cognition and language processing that significantly contributes to the field of linguistics, particularly in language development and special education.

4.1.5 Cluster 5 (purple colored)

The keywords in cluster 5 cover different facets of visual cognition research utilising eye-tracking technology. This theme encompasses the intricate processes by which we perceive, interpret, and respond to visual stimuli, integrating aspects such as attention, depth perception, orientation, and spatial perception. The keywords also include the physiological mechanisms underlying vision, the role of saccadic eye movements in visual search, and the importance of reaction time and psychomotor coordination in executing physical actions based on sensory inputs.

It is well-established that attention is most accurately measured using eye-tracking methods because the metrics allow researchers to objectively quantify the duration of fixations, the allocation and direction of visual preference in specific AOIs, and the patterns of saccadic movements. This data provides insights and indicators into how individuals selectively concentrate on specific visual stimuli, filter out irrelevant information, and manage cognitive load during various tasks, enhancing our understanding of attentional

processes and their impact on visual perception and psychomotor performance ([Harris et al., 2023](#)).

In addition, eye-tracking technology allows researchers to investigate how individuals perceive and navigate space. Using mobile eye trackers, researchers can capture real-time data on how people move and interact with their surroundings, providing valuable insights into spatial awareness, including depth, distance, orientation, localisation, and motion. This technology also facilitates the study of cognitive strategies employed in real-world settings and natural behaviours, such as navigating while driving or selecting products in a store. These findings contribute to a deeper understanding of how visual perception and spatial awareness interact to shape our engagement with the environment.

In one example, Li et al. ([2022](#)) conducted a study to explore how action video game playing influences eye movement behaviour during visual search tasks. The researchers compared the eye movements of action video game players (AVGPs) with non-players (non-AVGPs) to determine whether AVGPs have an advantage in visual search efficiency. The study found that AVGPs demonstrate a significant advantage in response (shorter reaction time) and eye-movement behaviour (shorter fixation duration, faster saccade velocity) during visual search tasks. This may be due to the enhanced ability to use visual cues and the attentional and visual processing skills developed through gaming. Additionally, AVGPs may have greater precision in their visual field, which significantly improves their visual search, particularly for rapid and accurate identification of targets and distractors.

4.1.6 Cluster 6 (turquoise colored)

The keywords in cluster 6 revolve around the interaction between mental states and cognitive processes, such as attentional bias and arousal in response to visual stimulation. Previous studies have shown that mental states and emotions such as anxiety, fear, happiness, and sadness significantly impact cognitive processes like attentional bias, perception, emotional reactivity, and arousal ([Zsidó, 2024](#)). Alon et al. ([2023](#)) examined how trauma exposure and PTSD affect attention allocation and bias using eye-tracking technology. The study found that individuals with PTSD or significant trauma exposure exhibit a stronger and more consistent attentional bias towards threatening and negative stimuli. These findings suggest that eye-tracking can offer valuable insights into the cognitive mechanisms underlying anxiety and PTSD.

Similarly, the study by Li et al. (2023) found that individuals with depression, whether or not they experienced suicidal ideation, detected suicide-related stimuli more quickly than healthy controls. This heightened detection may be attributed to an automatic hypervigilance towards threat and danger.

In addition to eye movements, pupillary response serves as a key indicator of emotional and affective states. Research has demonstrated that pupil dilation reflects underlying emotional and cognitive processes (Bardeen & Daniel, 2017; Keil et al., 2018; Macatee et al., 2017). Changes in pupil diameter are frequently associated with cognitive load, emotional arousal, and stress levels, making this physiological response a valuable tool for assessing cognitive and emotional reactions across different contexts and populations.

4.1.7 Cluster 7 (orange colored)

The keywords in cluster 7 highlight EEG as a brain modality measurement. Several research studies integrate EEG with eye-tracking to capture both behavioural and neural data, yielding a comprehensive understanding of cognitive processes. Using data from two distinct modalities enables researchers to correlate eye-movement or pupil-response data with associated brain activity. The integration of these methods allows researchers to simultaneously monitor where a person is looking and the corresponding neural responses, as both modalities offer high temporal sensitivity. For instance, EEG and eye-tracking have been employed in various research areas, including research on cognitive load (Scharinger et al., 2023; Zheng et al., 2024), language processing (Huang et al., 2023), emotional responses (Feldmann et al., 2023), spatial navigation (Qin et al., 2024), and virtual reality (Baceviciute et al., 2022; Larsen et al., 2024).

In addition to combining EEG and eye-tracking, research in the behavioural sciences also incorporates functional magnetic resonance imaging (fMRI) data. Using fMRI enhances the validity of research findings by providing converging evidence from multiple measurement techniques. With its high spatial resolution, fMRI can accurately localise brain activity to specific regions, where it can provide greater precision in understanding neural processes (Ceh et al., 2021; Lian et al., 2023; Yuen et al., 2021). However, the integration of fMRI with eye-tracking remains relatively scarce compared to its combination with EEG.

4.2 Impacts and contributions

Understanding the evolution of eye-tracking research is crucial for advancing both theoretical and applied knowledge in behavioural sciences. This study provides insight into how the field has developed, which themes have gained prominence, and where the research gaps remain for further investigation.

From a theoretical perspective, this study contributes by synthesising key thematic areas and providing a structured overview of dominant and emerging research directions. For instance, the findings reveal limited research on integrating eye-tracking with neurophysiological measures, suggesting opportunities for advancing integrative models of gaze-based cognitive processing. The study also addresses the lack of a comprehensive bibliometric synthesis in the area. Furthermore, this study connects eye-tracking applications to broader theories and models of visual attention, cognitive processing, educational technologies, and human-computer interaction. This connection helps establish a foundation for future hypothesis-driven studies.

Methodologically, this study improves bibliometric work by using a systematic approach that integrates citation analysis, thematic mapping, and co-authorship networks. This approach provides an objective measure of research progress and serves as a replicable framework for future bibliometric studies in the behavioural and cognitive sciences. The use of VOSviewer enhances the methodological rigour of the process by enabling the visualisation of keyword co-occurrence patterns, citation relationships, and thematic clusters, which allows for a more comprehensive and structured exploration of the literature. As eye-tracking research becomes more interdisciplinary, these contributions help researchers adopt more structured, data-driven methodologies and improve the reliability of future empirical and bibliometric studies.

Practically, this study highlights underexplored areas in clinical diagnostics and multimodal applications of eye-tracking, particularly its integration with neurophysiological tools and real-world behavioural assessments. These insights offer practical value to researchers, clinicians, and industrial professionals. Researchers can refine methodological approaches and explore emerging questions grounded in current research trends. Clinicians may leverage these findings to enhance cognitive assessments, neurological diagnostics, and mental health interventions. Industrial

professionals can integrate eye-tracking into user experience testing, advertising, and workplace ergonomics.

Therefore, by connecting bibliometric insights to real-world applications, this study enhances theoretical understanding, methodological precision, and interdisciplinary collaboration. These contributions help ensure the continued impact of eye-tracking research across various fields.

4.3 Future directions

Based on the seven themes identified, future research should prioritise exploring the multifaceted applications of eye-tracking across diverse contexts within the behavioural sciences. Each theme offers unique opportunities to deepen understanding of human cognition and behaviour, both theoretically and in practical applications.

First, further exploration of driving behaviour using gaze data and pupil responses can lead to improvements in driver training programs and the development of advanced driver assistance systems. This research could focus on real-time applications in both simulated and real-world environments, providing valuable insights into how visual attention influences driving performance.

Second, the role of eye-tracking in social cognition is particularly promising for understanding complex social interactions. Future studies could investigate how eye-tracking, combined with physiological and behavioural measures, can be applied to naturalistic settings to reveal new aspects of social behaviour, especially in populations with communication difficulties.

Third, eye-tracking research on cognitive ageing and memory processes should prioritise longitudinal studies. These studies could help identify early markers of cognitive decline, offering potential pathways for early interventions aimed at preserving cognitive function in older adults.

Fourth, language comprehension and processing is another area where eye-tracking can be further explored. Future research could examine cross-linguistic differences and the impact of bilingualism on visual attention, which could lead to more effective language learning tools and strategies.

Fifth, expanding eye-tracking technology in visual cognition research could involve integrating it with

virtual and augmented reality environments. This approach would allow researchers to study visual processing in more dynamic and immersive contexts, opening up new avenues for understanding how visual information is processed in complex scenarios.

Sixth, the interaction between mental states and cognitive processes is an area ripe for further investigation. Research could focus on how different mental states, such as stress or fatigue, affect visual attention and cognitive performance, with practical applications in areas such as mental health monitoring and performance optimisation.

Finally, the integration of eye-tracking with EEG presents a powerful tool for advancing our understanding of the neural basis of cognitive processes. Future research should develop more synchronised systems that enable simultaneous recording in both laboratory and real-world settings, which could significantly enhance our ability to study the brain's response to visual stimuli.

5.0 IMPLICATIONS, LIMITATIONS, AND CONCLUSIONS

This study conducted a quantitative literature analysis using VOSviewer software on scientific articles on eye-tracking studies published in the behavioural sciences. The main objective of this study is to provide a comprehensive overview of the current state, thematic areas, and potential directions for future research. Eye-tracking technology has been increasingly applied across various domains, underscoring its significance for understanding complex cognitive and behavioural processes. The seven themes that emerged from this analysis highlight the diverse applications of eye-tracking, ranging from driving behaviour and social cognition to cognitive ageing and language processing. This reflects the growing importance of eye-tracking as a versatile tool in the behavioural sciences.

The current study has several implications that should be addressed. The first is that the results highlight the importance of continued investment in research-grade eye-tracking devices to advance research across diverse domains of the behavioural sciences. The identified themes provide a roadmap for future research that can be conducted and built based on existing knowledge to explore novel applications of eye-tracking.

Second, integrating eye-tracking with other modalities, such as EEG, offers a promising direction for future research. Eye-tracking only reveals gaze behaviour and pupil response, but cannot explain neural mechanisms.

EEG complements eye-tracking by capturing brain activity linked to attention, cognitive load, and emotion. The combination enables more comprehensive data and a deeper understanding of the neural mechanisms underlying behaviour, allowing for a more refined interpretation of cognitive processes.

Additionally, EEG-integrated eye-tracking helps researchers understand how neural activity changes across cognitive states. It also refines theoretical models of attention and decision-making. By addressing interpretational gaps in standalone eye-tracking studies, EEG strengthens behavioural science research and expands its interdisciplinary applications.

Third, with technological advancements, integrating machine learning with eye-tracking data offers significant potential to overcome key limitations in current research. Traditional eye-tracking studies often struggle with manual data interpretation, limited scalability, and difficulty in detecting subtle gaze patterns in complex environments. Machine learning algorithms can address these challenges by automating the analysis of large datasets and improving accuracy in detecting patterns related to cognitive load, emotional states, fatigue, and user interest. In human-computer interaction, these algorithms can analyse gaze data in real-time to predict user intent, adapt interfaces, and deliver personalised feedback. Dynamic adaptation can improve the user experience by responding to individual behavioural cues.

In educational settings, machine learning models can support personalised learning by identifying gaze-based indicators of confusion, attention lapses, or engagement, enabling the system to adjust to learning materials in real time. Hence, by enhancing the scalability, precision, and adaptability of eye-tracking research, machine learning expands its practical applications while addressing core methodological limitations.

Fourth, the findings of this study highlight the importance of interdisciplinary collaboration. By combining expertise from psychology, neuroscience, computer science, and engineering, researchers can enhance eye-tracking methodologies and extend their use to new areas within the behavioural sciences. The development of advanced algorithms by experts in different fields can undeniably improve the analysis and interpretation of eye-tracking data, facilitating more precise models of human behaviour. This collaborative

approach will be essential for advancing eye-tracking research and its future applications.

This study has several limitations. The source of scientific articles for the analysis was gathered from the SCOPUS database. Therefore, the findings primarily reflect the research trends and themes captured within this database. Future studies could benefit from expanding the scope to include additional databases, providing a broader perspective on the field of eye-tracking in behavioural sciences.

The analysis and discussion are also limited to articles retrieved using specific keywords. As a result, the findings reflect the research areas most prominently associated with these terms. Expanding the range of keywords in future studies could uncover additional insights and trends within the broader field of eye-tracking in behavioural sciences.

Other than that, the citation metrics are limited to a select set of articles. This means that the analysis focuses on the influence and reach of those specific publications within the field. Future research could explore a broader range of citation metrics to gain a more comprehensive understanding of the impact and interconnectedness of studies across different areas of eye-tracking research.

In conclusion, given the dynamic nature of ongoing eye-tracking research spanning many domains, this field continues to expand and diversify. The diverse applications of eye-tracking technology highlight its critical role in advancing behavioural sciences. As time passes, new methodologies and interdisciplinary collaborations emerge, and eye-tracking research is becoming increasingly significant for understanding human behaviour and cognition

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