

Analysis of Research Hotspots and Trends in Autism Eye Movement Studies Based on CiteSpace Software

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Abstract: The analysis of hot spots and trends in autism eye movement research is of great significance to the further development of autism research. This paper uses 915 valid documents screened from the Web of Science Core Collection database as a sample, and uses CiteSpace 6.1R6 software to analyze the hot spots and future research trends of autism eye movement research from 2008 to 2023. The study shows that in recent years, the research in this field has generally shown an upward trend, but it has shown a downward trend after reaching a peak in 2021; the cooperation between authors needs to be strengthened; each cluster in this field has a relatively clear research theme, and the keywords contained in the cluster are closely related; the latest research hotspot is artistic features (autistic trait).

Keywords: Autism; Eye Movement Research; Citespace; Trend Analysis; Cluster Analysis.

1. Introduction

1.1. Research Background and Importance

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by difficulties in social communication, stereotyped behavior patterns, and narrow interests[1]. In recent years, eye movement research, as a non-invasive research method, has gradually occupied an important position in autism research. Through eye tracking technology, researchers can accurately capture the dynamic changes of individuals in the process of visual information processing and reveal the differences in visual attention, facial expression recognition, etc. among autistic individuals[2]. This research method can not only provide a scientific basis for the early diagnosis and intervention of autism, but also provide a new perspective for understanding the neural mechanisms of autism[3].

Existing studies have shown that autistic individuals have significant differences in facial recognition, social cue processing, etc., and these differences can be analyzed in detail through eye tracking technology[4]. For example, some studies have found that when autistic children look at facial expressions, they tend to avoid the eye area and pay more attention to the mouth or background. This unique gaze pattern may be an important reason for their social communication difficulties[5]. In addition, eye movement research also reveals the specificity of autistic individuals in terms of attention allocation and information processing speed, which is of great significance for understanding the core symptoms of autism [6].

1.2. Research Objectives

This study aims to systematically sort out the main hot spots and development trends of autism eye movement research from 2008 to 2023. By using CiteSpace 6.1R6 software, we conducted a knowledge graph analysis of the relevant literature. The specific goals include: first, identifying and analyzing the main research hotspots and frontiers of autism eye movement research; second, revealing the relationship between the main clusters and keywords in the research field; third, summarizing the main research

results and development trajectory in this field; fourth, exploring possible future research directions and trends to provide guidance and reference for further autism research.

2. Literature Review

2.1. Autism Research Review

Research into autism spectrum disorders involves multiple genetic and environmental factors and their interactions [7]. Initial studies were devoted to the description of autistic behavioral phenotypes and the formulation of diagnostic criteria, as it was first defined by Kanner back in 1943, and subsequent revision of autism criteria was done in DSM. With increasing development in science and technology, studies directed toward the biological basis of autism have evolved, mainly related to genetics and neuroimaging [8]. Just recently, through this brain imaging technology, researchers have found huge differences between the autistic and typical brain structure and function, particularly in those areas related to social cognition. On the other hand, some genetic studies of autism have revealed that many different genes are associated with the development of autism, including SHANK3 and CNTNAP2 [9-10]. Mutations in such genes may result in abnormal connections between neurons and deficits in synaptic function [11]. In addition, research on intervention and treatment strategies is also advancing. Behavioral intervention, drug therapy, and family and school support are the main means of autism intervention, among which applied behavior analysis (ABA) is widely considered to be one of the most effective intervention methods [12].

2.2. Review of Eye Movement Research

As a non-invasive research method, eye movement research has been widely used in the fields of psychology and cognitive science, especially in autism research [13]. Through eye tracking technology, researchers can explore the attention allocation patterns of autistic individuals in social scenes. For example, some studies have found that when autistic children watch facial expressions, they tend to avoid looking at the eye area and pay more attention to the mouth or background. This gaze pattern may reflect their difficulties in recognizing facial expressions [14]. In addition, autistic individuals show slower

reaction speed and lower attention maintenance ability when processing complex visual information [15]. Eye movement research can not only help reveal the specificity of autistic individuals in visual processing, but also provide new tools for early diagnosis and intervention of autism. For example, by analyzing infants' eye movement data, individuals at risk of autism can be identified early, thereby achieving early intervention [16]. In addition, eye tracking technology is also used to evaluate the effectiveness of interventions by comparing changes in individual eye movement patterns before and after intervention [17].

2.3. CiteSpace Software and its Applications

CiteSpace is a visualization software for analyzing scientific literature, developed by Professor Chen Chaomei. The software uses knowledge graph technology to reveal research hotspots, development trends, and knowledge structures in academic fields [18]. CiteSpace can process large-scale literature data and generate a variety of graphs including co-citation networks and keyword co-occurrence networks, providing researchers with rich information and insights [19]. In autism research, CiteSpace is widely used to analyze research hotspots and trends. Through co-citation analysis of related literature, core literature and important research topics in the field can be identified. Keyword co-occurrence analysis can reveal hot topics and cutting-edge directions in autism research, such as early diagnosis, intervention strategies, genetic research, etc. [20]. The application of CiteSpace is not limited to autism research, but is also widely used in scientific literature analysis in other fields, such as medicine, social sciences, education, etc. Researchers use CiteSpace to analyze literature data and reveal research hotspots and development trends in their respective fields [21].

3. Research Design

3.1. Research Methods

CiteSpace is a scientific knowledge graph drawing software developed by Professor Chaomei Chen of Drexel University in the United States. It is mainly used to realize knowledge visualization [22]. Through author and institution cooperation graphs, keyword co-occurrence, clustering and emergence, the software can not only reveal the independent and cooperative publications of authors and institutions in the research field, but also show the research development context, research hotspots and research frontiers in the field. The research results are finally presented in the form of a visual graph [23].

3.2. Data Source

This paper is based on the Web of Science Core Collection database, with the keywords "TS=autism AND TS=eye-tracking" for advanced search, and the article type is selected as "paper" and "review paper". 915 valid documents were screened.

3.3. Analysis Results

3.3.1. Distribution of Publication Period

Those 915 selected documents were published from 2008-2023. From Fig. 1, the number of publications in autism eye movement research has generally increased from 2008 to 2023, indicating that autism eye movement research has attracted increasing attention from scholars. Drawing from

the line chart below, which describes the trend of publication volume over time, one could say that while there was an increasing annual trend of publications from 2008-2014 and 2015-2021, peaking in 2021, recent years have experienced a drop each year regarding the number of publications. This at this moment shows that autism eye movement research has slowly been dying down in recent years.

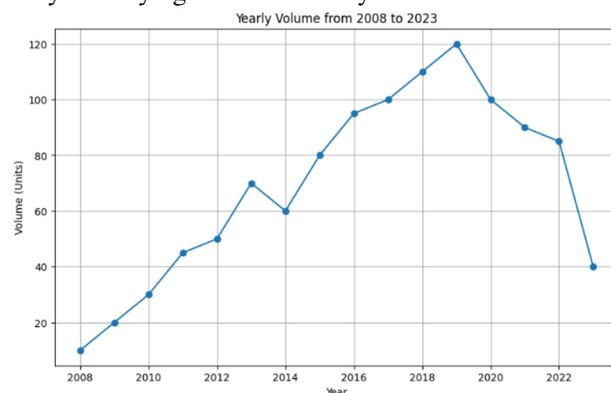


Figure 1. Trend of publications in autism eye movement research

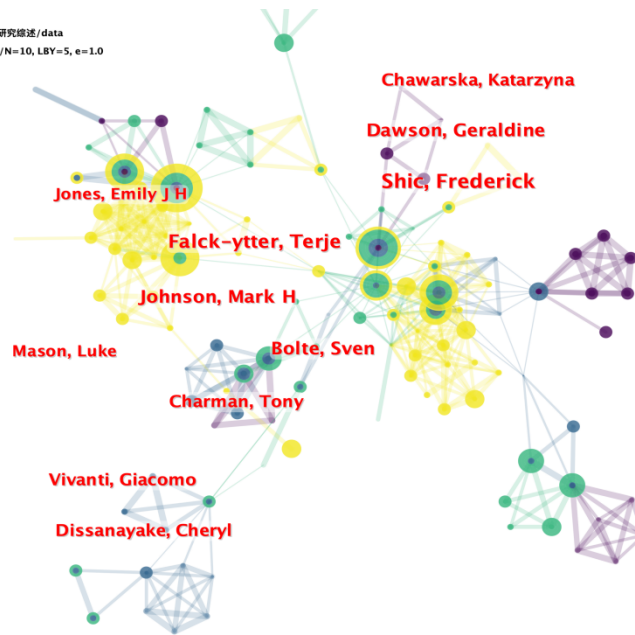
3.3.2. Author Cooperation Network Analysis

The author co-occurrence map can reveal the independent and cooperative publication of researchers. The higher the frequency of author publication, the larger the node. The connection represents the cooperation relationship between authors. In the parameter setting, the node type (Node Types) is set to Author, and the time slice (Years Per Slice) is set to 4 years to obtain the author cooperation network map. As shown in Figure 2, the number of nodes is 280, the number of connections is 652, and the network density is 0.0167. From the network density and the connection situation in the figure, it can be seen that there is cooperation between authors, but there are also scholars who publish independently. After analysis, it can be found that scholar Shic, Frederick has the most publications, reaching 30 articles, followed by scholar Falck-ytter, Terje and scholar Johnson, Mark H, with 24 and 20 articles respectively, and scholar Dawson, Geraldine and scholar Bolte, Sven have published 19 articles each. Among the scholars who published more papers, there was collaboration between Chawarska, Katarzyna, Dawson, Geraldine and Shic, Frederick, collaboration between Bolte, Sven and Charman, Tony, and collaboration between Vivanti, Giacomo and Dissanayake, Cheryl.

3.3.3. Analysis of Publishing Institutions

The institutional co-occurrence map can reveal the independent and collaborative publications of research institutions. The higher the frequency of publication of research institutions, the larger the node. The connection represents the cooperation between institutions. In the parameter setting, set the node type (Node Types) to institution (Institution) and the time slice (Years Per Slice) to 4 years to obtain the institutional cooperation network map. As shown in Figure 3, the number of nodes is 247, the number of connections is 844, and the network density is 0.0278. From the network density and the connection situation in the figure, it can be seen that there is a close cooperation between institutions. After setting the parameters, the six major publishing institutions are obtained as shown in Figure 3, namely Uppsala University in Sweden with 36 papers, Yale University with 32 papers, La Trobe University with 32 papers, King's College London with 31 papers, University of Washington with 29 papers, and Karolinska Institute with 28 papers.

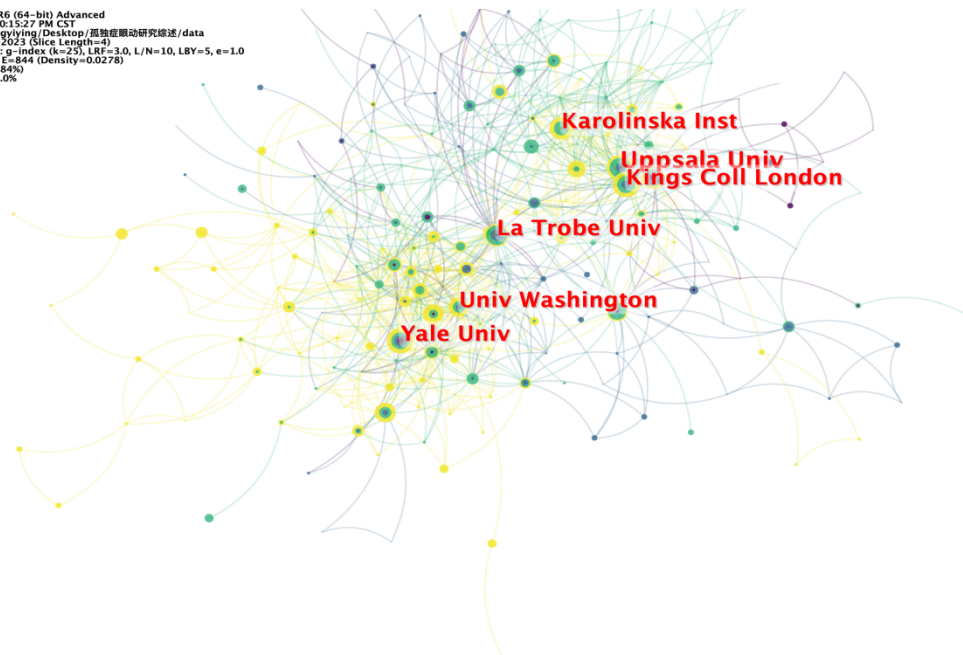
CiteSpace, v. 6.1.R6 (64-bit) Advanced
 June 9, 2023 at 3:13:10 PM CST
 WOS: /Users/wangyiyang/Desktop/孤独症眼动研究综述/data
 Timespan: 2008-2023 (Slice Length=4)
 Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LBY=5, e=1.0
 Network: N=280, E=652 (Density=0.0167)
 Largest CC: 128 (45%)
 Nodes Labeled: 1.0%
 Pruning: None



CiteSpace

Figure 2. Collaboration network of authors in the field of autism eye movement research

CiteSpace, v. 6.1.R6 (64-bit) Advanced
 June 8, 2023 at 10:15:27 PM CST
 WOS: /Users/wangyiyang/Desktop/孤独症眼动研究综述/data
 Timespan: 2008-2023 (Slice Length=4)
 Selection Criteria: g-index (k=25), LRF=3.0, L/N=10, LBY=5, e=1.0
 Network: N=247, E=844 (Density=0.0278)
 Largest CC: 209 (84%)
 Nodes Labeled: 1.0%
 Pruning: None



CiteSpace

Figure 3. Collaboration network of institutions that publish papers in the field of autism eye movement research

3.3.4. Keyword Co-occurrence Analysis

Keywords are highly condensed versions of the main research content of the article. The frequency, relevance, and emergence of keywords can reveal the research hotspots, internal connections, and research frontiers in the research field. The higher the frequency of keyword occurrence, the larger the node. A line represents that the keywords have appeared together in the same document. The thicker the line, the higher the correlation between the two keywords. In the parameter setting, set the node type (Node Types) to keyword (Keyword) to obtain the keyword co-occurrence map, as shown in Figure 4. The number of nodes in the map is 467, the number of links is 921, and the network density is 0.0085. After parameter setting, we obtained fourteen key words: adolescent, amygdala, eye gaze, 1st year, face recognition,

deficit, eye movement, executive function, information, activation, facial expression, absence, behavior, and anxiety.

3.3.5. Keyword Cluster Analysis

Keyword cluster analysis can reveal different research topics in the field of autism eye movement research. On the keyword co-occurrence map page, click Find Clusters to cluster keywords, use the logarithmic maximum likelihood ratio method Log-Likelihood Ratio (LLR) to name the cluster, click Show the Largest K Clusters, set to display only 8 cluster modules, and get the keyword cluster map as shown in Figure 5. The cluster module value Q is 0.6795 ($Q > 0.3$ indicates that the cluster structure is significant), which shows that the keyword cluster structure is significant. The cluster average profile value S is 0.8502 ($S > 0.5$ indicates that the

cluster is reasonable, $S > 0.7$ indicates that the cluster is convincing), which shows that the clustering effect is good,

each cluster in the field of autism eye movement research has a clear research theme, and the keywords contained in the cluster are closely related.

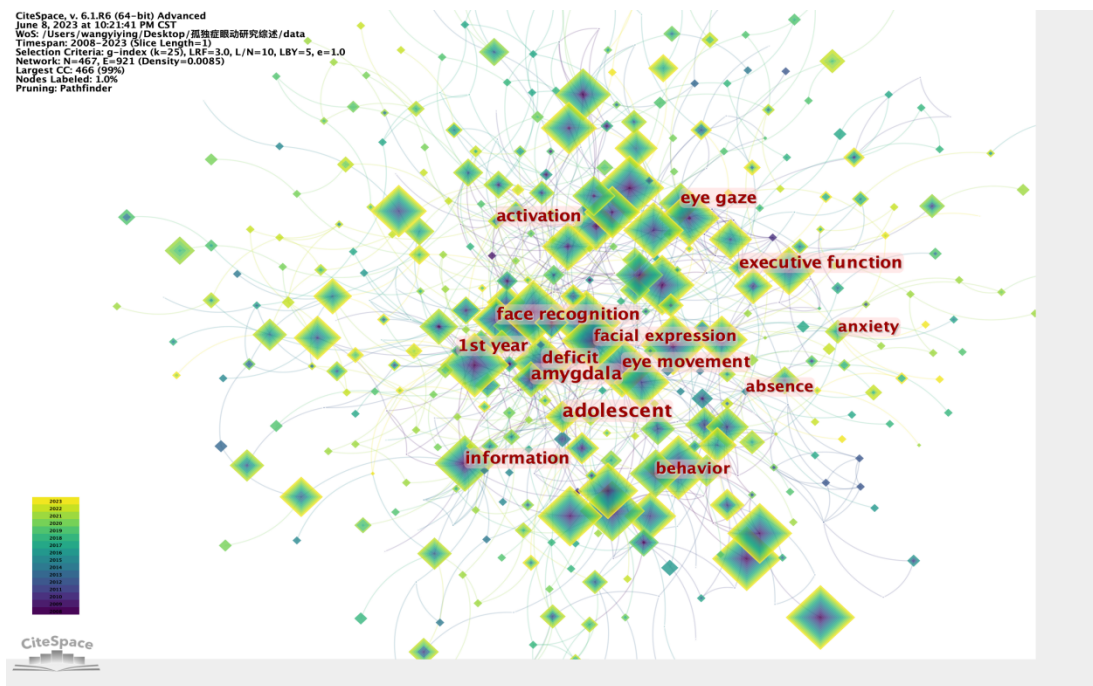


Figure 4. Co-occurrence map of keywords in autism eye movement research

Sorted by the number of keywords contained in the cluster, the keyword labels of these eight cluster modules are: eye movements, receptive language, broad autism phenotype,

pupil dilation, autonomic nervous system, joint attention, virtual reality, and social cognition.

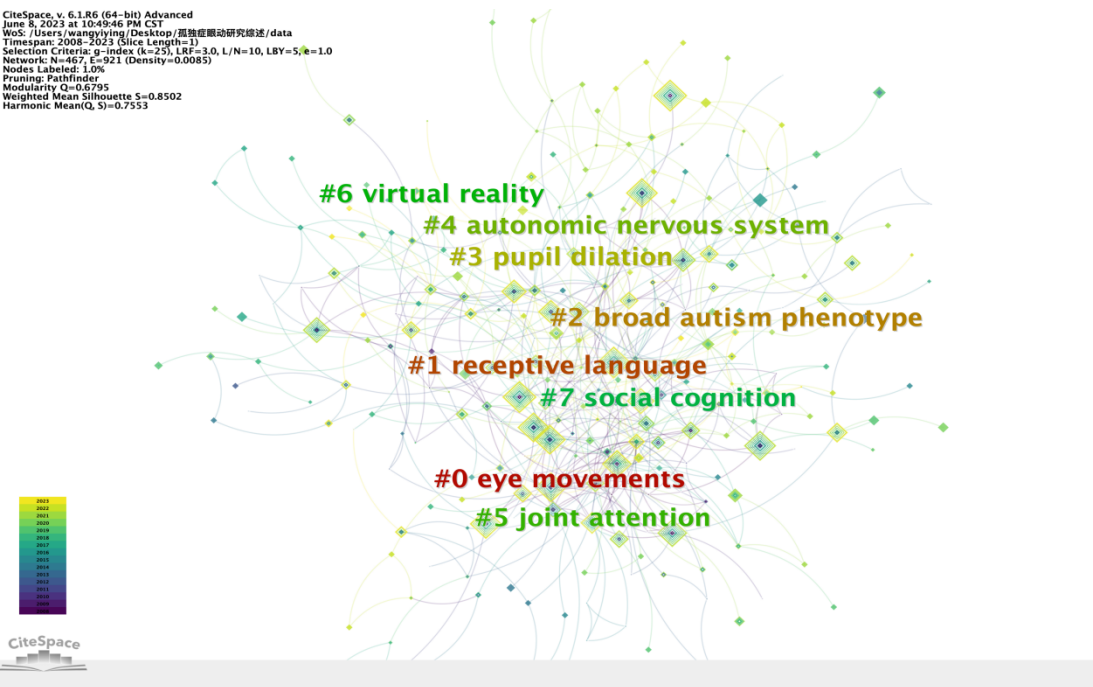


Figure 5. Clustering of keywords for autism eye movement research

3.3.6. Evolution of Research Context

According to the Timezone View function of CiteSpace, keywords can be arranged on the map in the order of their first appearance to show the research development context of the research field in different periods. In the parameter setting, since the time span of the observation year is not large, in order to improve the analysis accuracy, the time slice is set to 1, and click Timezone View to obtain the keyword co-

occurrence time zone map, as shown in Figure 6. After setting the parameters, the keywords with higher frequency are displayed. It can be seen that most of the keywords appeared from 2008 to 2012, which is also the stage when the number of publications shown in Figure 1 has steadily increased year by year. After 2021, no high-frequency keywords have emerged, which is consistent with the trend of decreasing publications since 2021 obtained from the analysis of Figure

1. At the same time, from the keywords emerging in Figure 6, it can be seen that the research trend is developing towards

the emotional and social fields.

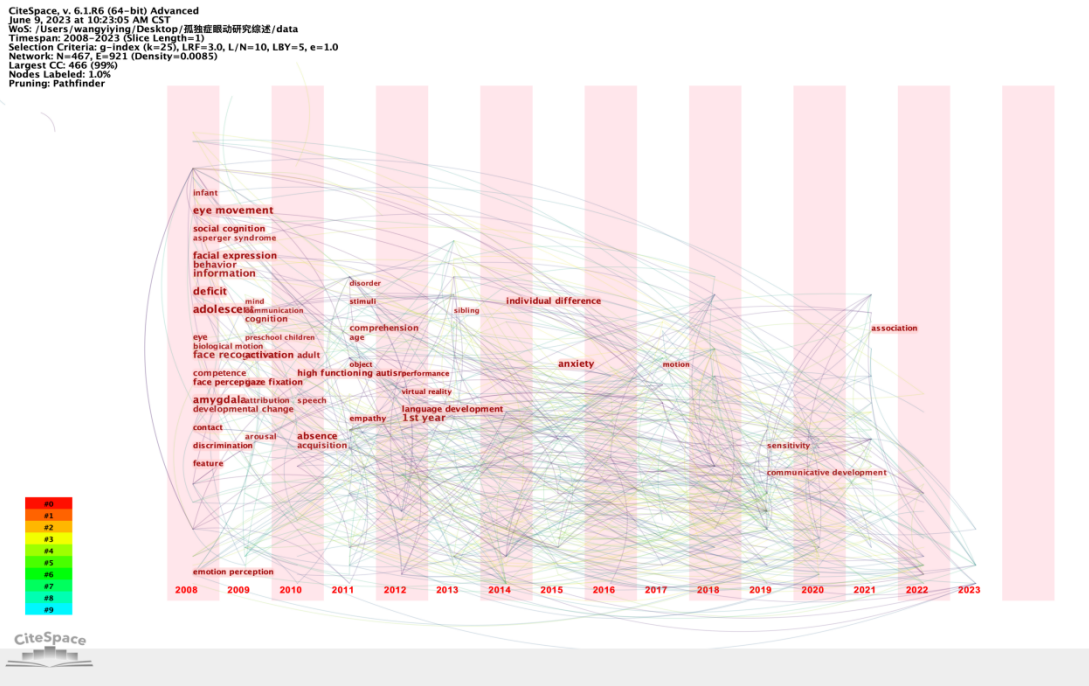


Figure 6. Autism eye movement research keywords co-occurrence time zone map

3.3.7. Research Frontiers and Trends

Burst detection technology can be used to identify the frontier hot words in the current water environment

governance research field. This technology mainly determines the prominent words based on the growth rate of words in the literature. The prominence of the prominent words reflects the strength of the research hotspot.

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2008 - 2023
fixation	2008	6.14	2008	2012	[Bar chart showing burst from 2008 to 2012]
face perception	2008	4.54	2008	2015	[Bar chart showing burst from 2008 to 2015]
asperger syndrome	2008	4.47	2008	2012	[Bar chart showing burst from 2008 to 2012]
deficit	2008	3.62	2008	2013	[Bar chart showing burst from 2008 to 2013]
diagnostic interview	2008	3.57	2008	2014	[Bar chart showing burst from 2008 to 2014]
williams syndrome	2009	5.68	2009	2016	[Bar chart showing burst from 2009 to 2016]
perception	2009	4.54	2009	2011	[Bar chart showing burst from 2009 to 2011]
gaze	2008	3.88	2009	2013	[Bar chart showing burst from 2009 to 2013]
preschool children	2009	3.26	2009	2014	[Bar chart showing burst from 2009 to 2014]
face recognition	2008	4.01	2010	2014	[Bar chart showing burst from 2010 to 2014]
facial expression	2008	3.63	2010	2015	[Bar chart showing burst from 2010 to 2015]
memory	2011	4.13	2011	2015	[Bar chart showing burst from 2011 to 2015]
disorder	2011	3.44	2011	2013	[Bar chart showing burst from 2011 to 2013]
neural circuitry	2013	4.05	2013	2014	[Bar chart showing burst from 2013 to 2014]
looking	2009	3.63	2013	2015	[Bar chart showing burst from 2013 to 2015]
social interaction	2014	6.34	2014	2017	[Bar chart showing burst from 2014 to 2017]
individual difference	2014	3.91	2017	2018	[Bar chart showing burst from 2017 to 2018]
validation	2018	7.15	2019	2021	[Bar chart showing burst from 2019 to 2021]
scene	2017	3.3	2019	2021	[Bar chart showing burst from 2019 to 2021]
connectivity	2019	3.3	2019	2020	[Bar chart showing burst from 2019 to 2020]
skill	2011	3.82	2020	2021	[Bar chart showing burst from 2020 to 2021]
disengagement	2020	3.27	2020	2021	[Bar chart showing burst from 2020 to 2021]
machine learning	2019	6.41	2021	2023	[Bar chart showing burst from 2021 to 2023]
metaanalysis	2017	6.26	2021	2023	[Bar chart showing burst from 2021 to 2023]
autistic trait	2021	3.45	2021	2023	[Bar chart showing burst from 2021 to 2023]

Figure 7. Top 25 emerging keywords in the literature on autism eye movement research

It can be seen that the top 25 research hot words in the field of autism research are arranged in order of appearance time, including: fixation, face perception, Asperger syndrome,

deficit, diagnostic interview, Williams syndrome, perception, gaze, preschool children, face recognition, facial expression, memory, disorder, neural circuitry, looking, social interaction,

individual difference, validation, scene, connectivity, skill, disengagement, machine learning, meta-analysis, and autistic trait. Face perception and Williams syndrome are the two keywords with the longest hotspot maintenance time, which were 2008-2015 and 2009-2016 respectively, both reaching 8 years, indicating that the outbreak cycle of these two keywords is long, the time span is large, and they have a lasting influence. Validation is the keyword with the highest emergence intensity, with a mutation value of 7.15. The latest hot word is autistic trait, which also shows that at this stage, the hot trend of autism eye movement research is leaning towards autistic trait, which also provides a research direction for subsequent research.

4. Discussion

In the past decade, the number of eye movement studies on autistic individuals has surged. Eye tracking technology allows researchers to measure with high accuracy what subjects are looking at and how long they are looking, thus providing evidence for the allocation of individual visual attention. Therefore, eye tracking technology is an excellent method to examine subtle changes in the visual patterns of autistic individuals. Socially oriented eye movement characteristics can be used as an important indicator for symptom screening of autistic children and have an enlightening effect on educational intervention. Therefore, the analysis of hot spots and trends in autism eye movement research is of great significance for the further development of autism research. However, according to the analysis of the number of publications and the time co-occurrence map of keywords, since 2021, the research hotspots in this field have shown a downward trend, so research in this field should be strengthened and new keywords should be continuously discovered. At the same time, authors can strengthen cooperation and increase the number of joint publications. Each cluster in the field of autism research has a relatively clear research theme, and the keywords contained in the cluster are closely related. According to the latest hot words, the research hotspot in this field is the field of artistic features (autistic trait), and in subsequent research, more research in this area can also be inclined.

5. Conclusion and Future Work

5.1. Main Conclusion

This study analyzed 915 autism eye movement research papers in the Web of Science Core Collection database from 2008 to 2023 using CiteSpace 6.1R6 software. The results showed that autism eye movement research has generally shown an upward trend in the past 15 years, but has declined after reaching a peak in 2021. This shows that the field of autism eye movement research has received increasing attention and research in the past decade, but the heat has weakened in recent years. Author collaboration network analysis shows that although there is collaboration between some scholars, the overall level of collaboration still needs to be improved. Keyword co-occurrence and cluster analysis revealed research hotspots and themes in this field, including keywords such as "face recognition", "social cognition", and "joint attention". The latest research hotspots focus on "artistic features", indicating that research in this field is developing in a new direction.

5.2. Research Limitations

Although this study systematically analyzed the hotspots and trends of autism eye movement research, there are still some limitations. First, this study is based only on the literature in the Web of Science Core Collection database, which may ignore relevant studies in other databases, which may lead to insufficient research coverage. Second, the analysis results of CiteSpace software depend on the quality of literature citations and keyword annotations. If the literature annotations are inaccurate or there are omissions, the accuracy of the analysis results may be affected. In addition, the time span of this study is from 2008 to 2023. Although it can reflect the research trends in the past 15 years, it cannot predict the future development direction, which requires continuous tracking and updating.

5.3. Future Research Directions

Future autism eye movement research can be expanded from the following directions. First, researchers should strengthen interdisciplinary cooperation, combine knowledge from multiple fields such as neuroscience, psychology, and education, and deeply explore the eye movement characteristics and neural mechanisms of autistic individuals. Second, future research should pay more attention to early diagnosis and intervention, and find identification signs of early autism risk by analyzing the eye movement data of infants and young children. Third, with the development of technology, new technologies such as virtual reality (VR) and machine learning will be more and more widely used in autism research, and these technologies can be used to improve the accuracy and practicality of research. Finally, considering that "artistic characteristics" have become a new research hotspot, more research can be done in the future to explore the performance of autistic individuals in artistic activities and their potential educational and therapeutic significance, providing new ideas for autism intervention.

References

- [1] Jackson, A. S., Bulat, A., Argyriou, V., Tzimiropoulos, G.: Large pose 3D face reconstruction from a single image via direct volumetric CNN regression. 2017 IEEE International Conference on Computer Vision (ICCV), pp. 1031-1039(2017).
- [2] Klin, A., Jones, W., Schultz, R., Volkmar, F., Cohen, D.: Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59(9), 809-816(2002).
- [3] Jones, W., Klin, A.: Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. *Nature*, 504(7480), 427-431(2013).
- [4] Sasson, N. J., Elison, J. T., Turner-Brown, L. M., Dichter, G. S., Bodfish, J. W.: Brief report: Circumscribed attention in young children with autism. *Journal of Autism and Developmental Disorders*, 41(2), 242-247(2011).
- [5] Pelphrey, K. A., Morris, J. P., McCarthy, G.: Neural basis of eye gaze processing deficits in autism. *Brain*, 128(5), 1038-1048(2005).
- [6] Chawarska, K., Macari, S., Shic, F.: Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders. *Biological Psychiatry*, 74(3), 195-203(2013).

- [7] Volkmar, F. R., Paul, R., Klin, A., Cohen, D.: *Handbook of Autism and Pervasive Developmental Disorders*. John Wiley & Sons, 2005.
- [8] Kanner, L.: Autistic disturbances of affective contact. *Nervous Child*, 2, 217-250(1943).
- [9] Belmonte, M. K., Cook, E. H., Anderson, G. M., et al.: Autism as a disorder of neural information processing: directions for research and targets for therapy. *Molecular Psychiatry*, 9(7), 646-663(2004).
- [10] Courchesne, E., Pierce, K., Schumann, C. M., et al.: Mapping early brain development in autism. *Neuron*, 56(2), 399-413(2007).
- [11] Betancur, C.: Etiological heterogeneity in autism spectrum disorders: more than 100 genetic and genomic disorders and still counting. *Brain Research*, 1380, 42-77(2011).
- [12] Dawson, G., Rogers, S., Munson, J., et al.: Randomized, controlled trial of an intervention for toddlers with autism: the Early Start Denver Model. *Pediatrics*, 125(1), e17-e23(2010).
- [13] Rayner, K.: Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124(3), 372-422(1998).
- [14] Klin, A., Jones, W., Schultz, R., Volkmar, F.: The enactive mind, or from actions to cognition: lessons from autism. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358(1430), 345-360(2003).
- [15] Speer, L. L., Cook, A. E., McMahon, W. M., Clark, E.: Face processing in children with autism: effects of stimulus contents and type. *Autism*, 11(3), 265-277(2007).
- [16] Jones, E. J. H., Venema, K., Lowy, R., Earl, R. K., Webb, S. J.: Developmental changes in infant brain activity during naturalistic social experiences. *Developmental Psychobiology*, 58(2), 265-280(2016).
- [17] Klin, A., Shultz, S., Jones, W.: Social visual engagement in infants and toddlers with autism: early developmental transitions and a model of pathogenesis. *Neuroscience & Biobehavioral Reviews*, 50, 189-203(2015).
- [18] Chen, C.: CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the American Society for Information Science and Technology*, 57(3), 359-377(2006).
- [19] Chen, C., Ibekwe-SanJuan, F., Hou, J.: The structure and dynamics of co-citation clusters: A multiple-perspective co-citation analysis. *Journal of the American Society for Information Science and Technology*, 61(7), 1386-1409(2010).
- [20] Börner, K., Chen, C., Boyack, K. W.: Visualizing knowledge domains. *Annual Review of Information Science and Technology*, 37(1), 179-255(2003).
- [21] van Eck, N. J., Waltman, L.: Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523-538(2010).
- [22] Chen, Y., Chen, C., Liu, Z., et al.: Methodological functions of CiteSpace knowledge mapping [J]. *Studies in Science of Science*, 33(2), 242-253(2015).
- [23] Yuan, X., Yan, D., Wu, Y.: Analysis of research hotspots and trends in domestic water environment management based on CiteSpace software [J]. *Sichuan Environment*, 42(2), 149-156(2023). DOI: 10.14034/j.cnki.schj.2023.02.022.