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Bridging Brains and Bots: The Influence of Intelligent Systems on Consumer Insights

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Abstract:
This paper provides a contemporary bibliometric review and examines the changing dynamics of the integration between advanced technologies and consumer behaviour insights. It methodically examines an extensive collection of academic articles, publications, and research findings to reveal trends and patterns at the crossroads of advanced technology and consumer behaviour insights. The review emphasises the advancements in methodologies, tools, and applications that have emerged from the fusion of cutting-edge technology and consumer behaviour insights. There has been a notable and steady rise in academic focus on the convergence of advanced technology and consumer behaviour analysis in recent years. The study also highlights the diverse approach of contemporary research in this area, incorporating disciplines like computer science, decision science, engineering, psychology, and medicine. The study is divided into five main areas: (1) the study of the brain and its structures; (2) techniques and tools for diagnostic imaging in neuroscience; (3) methods for processing and analysing signals; (4) the use of algorithms and neural networks; and (5) practical uses in understanding cognition and perception. The findings from the bibliometric analysis enhance our comprehension of the ongoing research landscape and offer a strategic direction for future studies, assisting scholars, practitioners, and policymakers in manoeuvring through the ever-evolving realm of advancements in the intersection of technology and marketing psychology.

Keywords: Bibliometric Review; Consumer Behavior; Neuromarketing.

1. INTRODUCTION:

The incorporation of advanced technology into marketing is emerging as a pivotal trend, reshaping how brands interact with customers, analyse data, and refine their marketing approaches [1]. Currently, around 2.55 percent of the industry's resources are allocated to advanced technologies, positioning marketing as the fourth largest sector for investment and the sixth for technology integration. The capacity of advanced technology to provide profound understanding of consumer behaviour is essential for drawing in and keeping customers, predicting their future actions, and transforming their overall experience.

Neuromarketing represents a cutting-edge domain that merges the principles of neuroscience with mark eting strategies, employing various neuroscientific techniques to uncover insights into consumer reactions to diverse stimuli. The main objective of neuromarketing is to gain a deeper understanding of human behaviour within the realm of marketing, providing insights that are frequently unattainable through conventional marketing research methods. Neuromarketing leverages advanced algorithms to analyse extensive datasets from neuroimaging studies, uncovering concealed patterns and correlations. This approach enhances marketing strategies and offers a deeper insight into consumer preferences, decision-making processes, and emotional responses.

The fusion of advanced technology with the study of brain activity signifies a transformative change in how we understand consumer behaviour and marketing strategies, merging sophisticated analysis with deep insights into the neurological factors that influence purchasing decisions. This integration significantly improves the accuracy and effectiveness of data analysis while revealing previously hidden dimensions of consumer decision-making. In light of the swift evolution and integration of brain science, intelligent systems, and promotional strategies, a thorough bibliometric analysis is crucial. This analysis seeks to uncover significant trends, primary contributors, and new research domains where advanced technology meets consumer behaviour insights, ultimately enhancing our comprehension of how cutting-edge tools elevate marketing strategies and suggesting novel avenues for future exploration. Even with the swift growth and broad sharing of knowledge in this area, there remains a significant absence of cohesive information, which complicates the ability for researchers to evaluate how well the literature addresses key subjects and identifies research voids [8]. Integrating research in this area is essential for enhancing our comprehension, formulating innovative theories, and influencing educational strategies within the discipline. Moreover, there is a significant lack of comprehensive research on the role of artificial intelligence in the e-commerce sector, even as it continues to evolve swiftly due to the influence of extensive data, sophisticated machine learning techniques, and cloud technology.

This study seeks to integrate findings on the intersection of advanced technology and consumer behaviour, outlining potential avenues for future exploration with two focused research questions: (1) What is the present landscape of research in this evolving field? What are the subsequent steps in this research domain? This paper brings together a variety of scholarly works to deepen the understanding of how technology is reshaping neuromarketing, emphasising the implications for both academia and industry. It aims to provide valuable insights for researchers, practitioners, and policymakers looking to harness technology to decode the intricate dynamics of consumer behaviour.

The paper is organised into five distinct sections, each clearly defined. Section 1 serves as an introduction, while Section 2 provides a review of the background and relevant work. Section 3 outlines the approach taken and provides an explanation of the research process employed. Section 4 explores the results and discussion, providing a critical analysis of the findings, while section 5 offers concluding remarks and highlights future research directions, ensuring a thorough overview of the study's implications and potential areas for further exploration.

2. THEORITICAL BACKGROUND:

Advanced technologies have fundamentally transformed the marketing landscape, providing innovative solutions that have redefined how companies interact with consumers. The cutting-edge advancements in the intersection of artificial intelligence and neuroscience highlight several key domains where these technologies are being utilised to revolutionise and improve marketing approaches:

2.1 Scale at Personalization:

Advanced technologies facilitate an unprecedented level of personalisation in marketing, empowering businesses to customise content, suggestions, and experiences to meet the unique preferences of each consumer on a large scale. By utilising advanced algorithms that sift through extensive data from user interactions, purchases, and browsing behaviours, these systems can forecast customer preferences with impressive precision and tailor marketing messages to fit individual needs. This ability greatly enhances interaction and conversion rates by providing pertinent content that aligns with the consumer's immediate needs and wants. Recent advancements in the field are facilitating large-scale personalisation through various significant methods: (1) Customised Campaigns: Advanced marketing automation tools can adapt messages and content to suit individual customers according to their interests, behaviours, and preferences [9]; (2) Analysing Unstructured Data: Advanced technologies can assist in examining detailed customer information, including unstructured feedback, to deliver more profound insights that shape highly personalised experiences [10]; (3) Process Automation: Advanced technology can streamline numerous marketing tasks, ranging from customer support to content generation, allowing human teams to concentrate on more strategic initiatives.

This enhances efficiency and facilitates more personalised interactions; and customised models are being developed by companies that go beyond standard AI solutions, training unique models on their proprietary data to create specialised capabilities tailored to specific business needs and customer bases.

2.2 Predictive Analytics:

Drawing from earlier research conducted by Sahai and Goel [13] Predictive analytics powered by advanced technology are utilised in marketing to anticipate consumer behaviours, buying trends, and possible churn rates. Utilising past data alongside immediate information, advanced models can discern patterns and forecast upcoming results. Earlier research indicates that advanced technology improves audience segmentation by examining data points that are too intricate for manual evaluation. It discerns nuanced patterns and behaviours that categorise consumers into precisely targeted segments. Marketers have the ability to leverage these segments to create exceptionally targeted campaigns that are more inclined to succeed, drawing on the distinct traits and preferences of each group [14]. A study by Perret and Heitkamp [15] highlights how systems utilise natural language processing (NLP) to comprehend and engage with customers, ultimately improving the customer experience, resulting in greater satisfaction and stronger brand loyalty.

2.3 Decison Making in Real-time:

The emergence of real-time data processing allows intelligent systems to swiftly respond to current market dynamics and provide immediate insights based on consumer behaviour feedback. This ability is essential during fast-paced occurrences like online sales, where algorithms modify marketing strategies instantly to take advantage of new trends and consumer reactions. The research conducted by Doe and Smith [16] explores the uses of advanced technology in marketing, highlighting its ability to enhance data management and software functionalities. This study highlights the immense possibilities of advanced technology in the marketing realm and its capacity to improve information and data resources. According to the study by Haleem et al. [17], cutting-edge tools have reached a level where they can produce innovative content across various formats, such as text, images, and videos. Advanced content creation tools leverage sophisticated algorithms to craft marketing messages that connect with specific audiences, enhance search engine visibility, and create engaging visuals. Additionally, advanced technology can evaluate various content

iterations to identify the most effective ones, enhancing marketing strategies for improved engagement and success.

2.4 Neuro Marketing: An Integration

The most recent advancements in artificial intelligence involve the incorporation of neuromarketing strategies to explore consumer psychology and emotional reactions more profoundly. Advanced algorithms analyse data from EEGs, fMRIs, and eye-tracking, providing insights that surpass conventional marketing analytics. This integration enhances the comprehension of the emotional drivers behind consumer behaviour, leading to the development of more impactful marketing strategies [18]. In the realm of neuromarketing, a research firm located in Atlanta, GA, has collaborated on projects with prominent companies such as Coca-Cola, Delta Airlines, and Home Depot, employing fMRI scanning to gain insights into consumer behaviour and decision-making [19]. A research paper by Fish et al. [20] explores the application of advanced technology in the realm of neuromarketing, focussing on advertising, branding, and consumer appreciation of products and services. The research highlights the capability of advanced technology to enhance the development of algorithms in the field of neuromarketing, indicating a bright future for technology-driven strategies in this area.

3. RESEARCH METHODOLOGY

The study employs bibliometric analysis to reveal research trends in the realm of advanced technologies and consumer behaviour by organising extensive data into various categories, including the number of publications, institutional collaborations, keyword occurrences, and more, ultimately charting research progress and pinpointing emerging concepts for future exploration [21]. The study's data were sourced and gathered from Scopus, recognised as one of the most comprehensive databases of indexed academic publications [22]. To search the database, we first defined a collection of terms linked to advanced cognitive strategies and innovative marketing techniques. We employed the Boolean operator "OR" to execute a query within the areas associated with "title," "abstract," and "keywords." The search formula utilised was: (ABS ("Neuromarketing" OR "Neuro-marketing" OR "Neuro Marketing" OR "FMRI" OR "functional magnetic resonance imaging" OR "f-MRI" OR "eye tracking" OR "electroencephalograph" OR "EEG" OR "face reader") AND ABS ("emotion") AND ABS ("AI" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "natural language processing"). Following the exclusion of non-English publications and refining the search to the fields of "Business, Management, and Accounting" and "Psychology," the results revealed 187 articles. These included details such as author names, titles, the corresponding author's country, total publication counts, citations, journal sources, keywords, and geographical regions. Additionally, the gathered database underwent a thorough manual review by examining the abstracts of the papers.

The study topic and content aligned with this research topic in various aspects. Irrelevant articles were discarded. Following the above process, 24 articles were deleted, and 163 articles were consistent with the topic direction. Factors leading to the removal included the research material conflicting with this study and the type of research aligning with this study [23].

The data were visualised (network and overlay) using VOSviewer version 1.6.20 to identify co-occurrence and clusters of related articles, countries, organisations, and author collaborations (co-authorship), along with clusters of interconnected research topics (text data) [24]. VOSviewer was employed to showcase the global partnerships among authors, institutions, and countries, along with the evolving patterns in research across various topics. The figures in this paper showcase items using a label accompanied by a

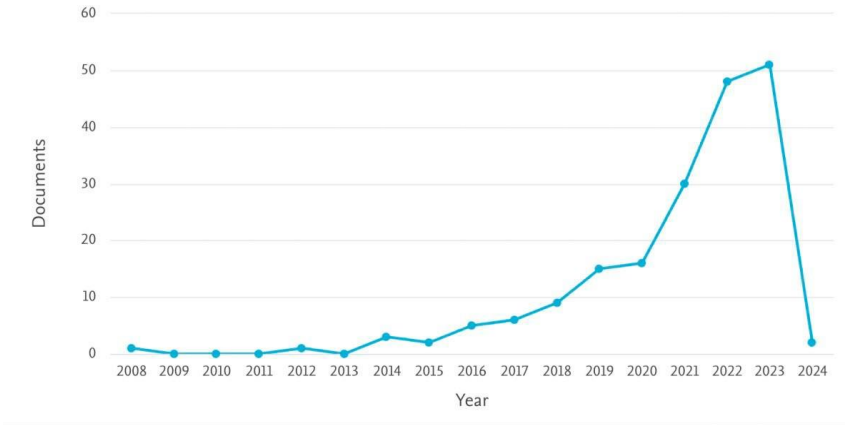
circle. The significance of an item is represented by the size of the circle. According to the program's calculations, the colors in the chain representation reflected arrays of related components. The strength of the relationships was represented by the distance between the items [25].

4. RESULT ANALYSIS AND DISCUSSIONS

4.1 Year-wise Publications:

We carried out an in-depth examination of the publication trends concerning advanced technologies and consumer behaviour insights from 2008 to February 2024. The results depicted in Fig. 1 reveal a notable and steady rise in academic engagement in this area over the past ten years. Between 2008 and 2015, the yearly publication rate remained steady, with an average of 1 to 3 papers released each year. Between 2016 and 2018, there was a slight rise to 5-9 publications annually, reflecting the nascent phase of research in this innovative field. Starting in 2018, there was a significant rise in yearly publications, surpassing 15 papers annually. This trend continued in the following years, with annual publishing rates fluctuating between 15 and 50 articles. The data reveals a steady rise in the volume of publications over the examined timeframe, with especially significant growth noted in the past three years, highlighting the increasing importance of this area in consumer research. A significant portion of the publications, specifically 68.6%, can be traced back to the years between 2021 and 2023, highlighting a notable increase in academic contributions during this period. This trend highlights the increasing acknowledgement of how advanced technologies can transform marketing approaches by providing profound insights into consumer behaviour and the intricacies of decision-making. The significant increase in publications in recent years underscores the vibrancy of the field and the ongoing endeavours of the research community to investigate the connections between advanced technology and consumer behaviour.

Fig. 1. The number of annual publications on AI and Neuromarketing indexed in Scopus 2008-2024.



4.2 Regional-wise Authorship Analysis:

A total of 44 countries or regions participated in the creation of the 163 papers for this study. Table 1 illustrates a remarkable duality in the research landscape, showcasing China as the foremost producer, while the United States exerts a notable and substantial influence on the global academic community. While China leads in the total amount of research output, it's important to highlight that publications from the United States receive significantly higher citation counts compared to their Chinese counterparts. The disparity in citation metrics clearly demonstrates significant global academic influence and standing [27].

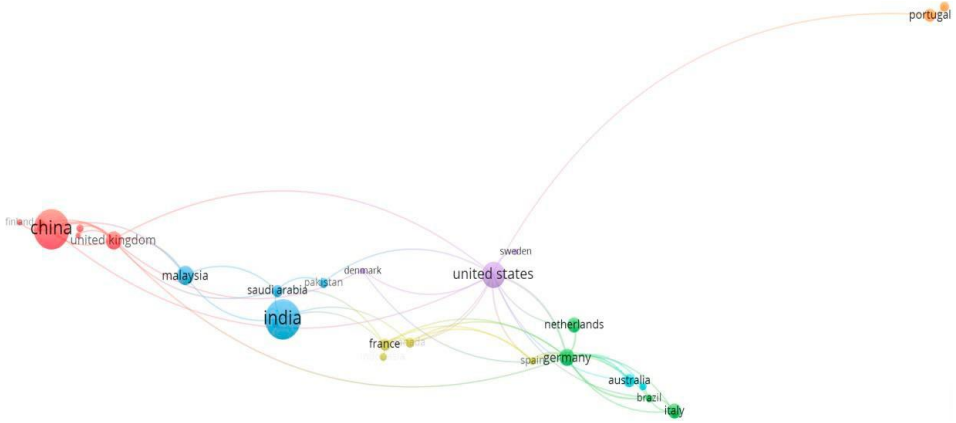
The elevated citation count associated with research from the United States suggests that, even though China produces a greater number of articles, U.S. research holds more significance and is perceived as more influential in the realms of AI and neuromarketing [28]. The gap between the amount of research produced and its academic significance underscores the intricate nature of scholarly impact and the diverse ways contributions shape the field. It not only reflects on the quantitative aspects of academic productivity but also on the qualitative dimensions of research, including innovation, applicability, and the capacity to advance theoretical and practical understandings in the field. The network visualisation showcases eight unique clusters, each represented by a different colour (Fig. 2). The largest circles for China, India, and the United States highlight their prominent roles in the volume of research output, showcasing these countries' significant contributions to the field.

The original group comprised seven nations and areas (highlighted in red): China, Finland, Hong Kong, Israel, Norway, Switzerland, and the United Kingdom. The second cluster comprised five countries/regions (green): Brazil, Germany, Italy, Mexico, and the Netherlands. The third cluster comprised five nations (blue): India, Malaysia, Pakistan, Peru, and Saudi Arabia. The fourth cluster included four countries and regions (yellow): Canada, France, Indonesia, and Spain. The fifth cluster was made up of three nations (violet): the United States, Sweden, and Denmark. The sixth cluster included a pair of nations (light blue): Australia and New Zealand. The seventh cluster included two nations (orange): Columbia and Portugal. The findings underscore the worldwide enthusiasm and cooperative spirit of research initiatives in this domain, highlighting robust international partnerships and thematic focusses within the discipline [30].

Table 1. The top 5 Countries/regions publishing articles on Scopus in the field of AI and Neuromarketing

Sl. No	Country	TP	Citation
1	China	43	257
2	India	42	188
3	United States	19	377
4	Malaysia	10	105
5	Japan	8	18

Fig. 2. The country co-authorship network of research on AI and Neuromarketing research.



4.3 Research Area Categories:

The Scopus database's interdisciplinary classification of research in the realm of AI and Neuromarketing spans a diverse array of fields. The dominant field, Computer Science, represents almost a quarter of the research output (23.64%), highlighting the essential importance of computational techniques, algorithms, and technologies in crafting and implementing AI-driven approaches in marketing strategies. The focus on Decision Science accounts for 18.91% of the literature, highlighting the exploration of consumer decision-making processes and the role of advanced technologies in improving insights and forecasts related to consumer behaviour. The field of engineering, holding an 11.09% share, showcases the integration of engineering principles in the development of tools designed for neuromarketing, including sophisticated sensors and measurement devices. The study of psychology, accounting for 8.54%, plays a vital role in grasping how consumers react cognitively and emotionally to marketing efforts, a field significantly enhanced by advanced analytical tools. Finally, the field of Medicine, especially neuroscience, represents 8.18%, highlighting the importance of understanding how medical insights influence brain reactions to marketing strategies. These categories collectively highlight the interdisciplinary convergence that defines the research landscape and emphasise the collaborative efforts necessary to enhance our comprehension and implementation of advanced techniques in this field.

4.4 Core Domain Journals

Table 2 shows that a considerable number of articles concerning recent research in the field were published in the Frontiers in Human Neuroscience Journal, which has an impact factor of 4.4, placing it in the second quartile (Q2) with 98 citations from 12 articles. This journal is highly esteemed as a premier publication in neuroscience, concentrating on cutting-edge research related to the human brain.

Table 2. The top 15 journals on Scopus for research on AI and Neuromarketing

Sl. No	Journal Name	TP	Citation	Ratio
1	Frontiers in Human Neuroscience	12	98	7,361
2	Smart Innovation Systems and Technologies	11	8	6,748
3	Frontiers In Psychology	8	71	4,908
4	Knowledge Based Systems	5	84	3,067
5	International Journal of Recent Technology & Engineering	3	16	1,840
6	Journal of Affective Disorders	3	14	1,840
7	Social Cognitive and Affective Neuroscience	3	14	0,018
8	International Journal of Psychophysiology	2	71	0,012
9	Psychophysiology	2	5	0,012
10	International Journal of Human-Computer Interaction	2	3	0,012
11	Nature Human Behaviour	1	172	0,006
12	Journal of Big Data	1	76	0,006
13	Transactions on Computational Social Systems	1	52	0,006
14	Egyptian Informatics Journal	1	47	0,006
15	Building and Environment	1	36	0,006

Despite the impact and reach of Frontiers in Human Neuroscience, the analysis reveals that the most cited articles within the research domain are predominantly published in Nature Human Behaviour, which holds

an impact factor of 29.9, positioning it in the first quartile (Q1) across multiple categories, including Multidisciplinary Sciences, Psychology, Experimental, and Neurosciences. This highlights the remarkable significance and acknowledgement of the article published in Nature Human Behaviour, emphasising its impact across multiple areas within the scientific community [32, 33].

4.5 Co-occurrence Network in keywords:

A total of 1248 keywords out of 84 exceeded the threshold of five, and these were organised into clusters that cover a wide range of research or technological domains. The initial cluster is encapsulated as the examination of "The Neuroscience and Brain Structure," concentrating on the anatomical components of the brain that play a role in emotion processing and cognitive functions [34]. Our findings revealed that there were significant connections among the brain cortex, amygdala, and anterior insula. The analysis of the study highlighted that the focus was primarily on the brain regions of the cortex, amygdala, and anterior, given their crucial involvement in emotional processing, decision-making, and cognitive functions. The amygdala plays a crucial role in emotional responses, especially those related to negative emotions, and is key in implicit (automatic) emotional processing [35]. Conversely, the anterior insula is linked to personal (explicit) emotional experiences and thoughtful decision-making. It serves an essential function in merging emotional experiences with cognitive and motivational mechanisms [36]. The prefrontal cortex, which encompasses the dorsolateral prefrontal cortex, plays a crucial role in cognitive control, attention, and working memory. Meanwhile, the ventromedial prefrontal cortex is tied to decision-making and the formulation of goals [37]. The interconnectedness of these brain regions plays a crucial role in the intricate relationship between emotions, cognition, and decision-making. This makes them vital areas of focus for examining consumer behaviour and the processes involved in making choices.

The second theme cluster, titled "Methodological Approaches and Neuroscience Tools for Diagnostics and Imaging", emphasises the cutting-edge methodologies and neuroscientific technologies utilised to visualise and analyse brain function and structure. This cluster plays a crucial role in research, offering essential methods for assessing and understanding the brain's reactions to different stimuli, activities, and emotional conditions. At the heart of this group are four essential methodologies that are often referenced: Electroencephalography (EEG), Functional Magnetic Resonance Imaging (fMRI), Eye Tracking, Face Recognition, and Virtual Reality [39].

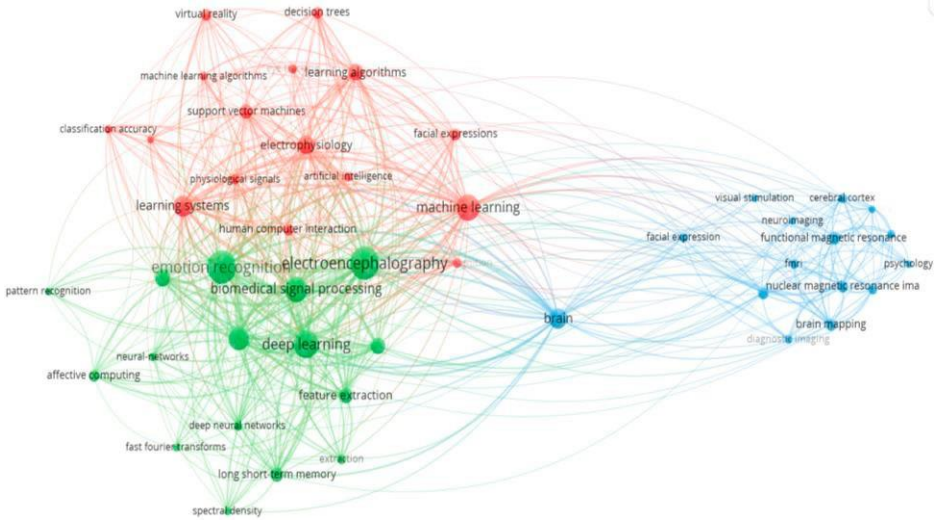
The incorporation of these tools in research has greatly enhanced our comprehension of consumer behaviour. Utilising a blend of EEG to capture brain electrical activity, fMRI to visualise brain activation patterns, eye tracking to assess visual attention, face recognition to gauge emotional responses, and VR to immerse consumers in realistic environments provides a thorough understanding of consumer reactions to marketing stimuli. The combination of neuroscience and advanced technology allows for a profound understanding of consumer preferences, emotional reactions, and decision-making behaviours, paving the way for innovative marketing strategies that foster more personalised, effective, and engaging experiences for consumers. When combined with advanced algorithms, these tools allow for the extraction of profound insights into consumer preferences, emotional reactions, and the intricacies of decision-making processes. The application of these methodologies showcases the advanced nature of the field and its dependence on neuroscience technology to connect marketing strategies with consumer psychology [41, 42].

Cluster 3, named "Signal Processing and Analysis", focusses on the techniques used to interpret physiological signals, which are crucial for research in neuroscience and for clinical diagnostic purposes. Through a co-occurrence analysis, it is evident that Fast Fourier Transforms (FFT) and Spectral Density

stand out as essential techniques in this area. FFT enables the transformation of signals from the time domain to the frequency domain, revealing the key frequencies and their relationships to neural activities [43]. At the same time, Spectral Density assesses how signal power is distributed across different frequencies, providing insights into particular brain functions or irregularities [44]. Both techniques provide a comprehensive insight into physiological signal behaviour, improving diagnostic capabilities and aiding advanced research in various fields.

Cluster 4, named "Machine Learning and Neural Networks," includes a range of algorithms and methods essential for data analysis, learning, and prediction. Essential concepts like Machine Learning, Learning Algorithms, Learning Systems, Deep Neural Networks (DNN), Convolutional Neural Networks (CNN), and Decision Trees highlight the synergy of these technologies in data-centric evaluations. Machine Learning serves as the essential basis for creating self-learning systems, with Neural Networks playing a vital role in capturing the intricacies of data [47]. Advanced techniques like DNNs and CNNs are revolutionising this area by allowing for the analysis of extensive data sets with remarkable depth and complexity. Learning Systems incorporate advanced algorithms that evolve and refine themselves over time, utilising complex networks and structured decision-making processes for superior outcomes. Decision Trees provide a clear and efficient method for both classification and regression, enabling the visualisation of decision-making processes [49]. This cluster emphasises the collaboration between machine learning and neural network technologies in enhancing data analysis, highlighting their combined significance in propelling innovations in the field of Neuromarketing.

Fig. 3. The number of annual publications on AI and Neuromarketing indexed in Scopus 2008-2024.



Cluster 5, labelled "Applications in Cognition and Perception", focusses on utilising technology to explore and improve human cognitive and perceptual abilities. This cluster is characterised by several crucial concepts, such as Affective Computing, Emotion Recognition, Speech Recognition, Brain-Computer Interface, and forecasting. Affective Computing centres on creating systems capable of recognising, interpreting, and simulating human emotions. This innovation allows devices to respond with greater emotional intelligence and human-like qualities, improving user experience through more personalised and responsive interactions. Technologies that recognise emotions examine human emotional states by utilising data from multiple sources, such as facial expressions, voice patterns, and physiological signals. This method is essential in the field of neuromarketing, as grasping consumer emotional reactions can lead to more

impactful marketing strategies. Voice recognition technology converts spoken words into text that machines can understand, facilitating smoother and more effective communication between people and devices. This enables a diverse array of uses, spanning from voice-activated helpers to automated customer support systems [51]. Brain-Computer Interfaces (BCIs) create a seamless link between the brain and external devices, allowing individuals to manipulate technology using their thoughts. This advancement holds great importance for improving the quality of life for individuals with severe physical disabilities, providing fresh opportunities for engagement and independence [52]. In this context, forecasting utilises advanced algorithms and analytical methods to anticipate future trends by examining past data. In cognitive and perceptual applications, forecasting serves to predict user behaviour, preferences, and emotional responses, allowing for a more personalised approach to technology that aligns with individual needs and desires [53]. These technologies embody a comprehensive strategy aimed at enhancing our grasp of human thought processes and sensory experiences, ultimately leading to the development of more intuitive, accessible, and tailored technological solutions, setting the stage for future innovations.

5. REMARKABLE CONCLUSION

The bibliometric analysis of research in this field shows a swiftly growing area marked by significant global contributions, interdisciplinary collaboration, and the application of innovative methodologies. The surge in research activity, especially over the past three years, highlights the rising enthusiasm for leveraging advanced technologies to gain profound consumer insights, signalling a transition towards more customised and impactful marketing strategies. The study showcases a wide-ranging international involvement, with significant input from countries like China and the United States, highlighting the global interest and cooperation in this field. The integration of various fields, including computer science, psychology, and neuroscience, plays a vital role in enhancing our comprehension of consumer behaviour through advanced algorithms and cutting-edge technologies. In summary, this bibliometric review underscores a vibrant and growing domain that is set to transform marketing approaches by offering deep insights into consumer decision-making processes, showcasing the potential to revolutionise marketing effectiveness and enhance consumer engagement. Our future work encompasses (1) examining the use of advanced technologies in particular sectors like healthcare, finance, or e-commerce to craft customised solutions and strategies; (2) delving into the fusion of these technologies with other cutting-edge innovations, such as virtual reality or augmented reality, to deliver engaging and personalised marketing experiences; and (3) creating sophisticated algorithms and models specifically designed for applications in this field, capable of process.

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