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NeuroIS: a State-of- the- Art Analysis

Nahid Entezarian[1], Mohammad Mehraeen[2*]

[1].Department of Management, Faculty of Economic and Administrative Science, Ferdowsi University of Mashhad, Mashhad, Iran
[2].Professor of Information Systems, Management Department, Ferdowsi University of Mashhad, Mashhad, Iran

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Abstract

NeuroIS, the interdisciplinary field merging neuroscience and information systems, has recently garnered significant attention for its potential to enhance our understanding of human behavior in the tech context. This analysis delves into the current NeuroIS research landscape, examining key trends, methodologies, and discoveries in the field. By synthesizing recent research, the aim is to shed light on potential applications of NeuroIS across various domains and identify future research directions in this rapidly evolving field. Currently an emerging area within information systems, NeuroIS has a limited number of studies available. To aid researchers entering NeuroIS, we have analyzed 244 articles and summarize their findings to give more details of NeuroIS studies. This examination of literature reveals various avenues for future NeuroIS exploration, including influencing factors, measurement tools, and subject areas. We believe that our work will offer valuable insights for upcoming NeuroIS studies. The fusion of neuroscience and information systems holds immense potential for uncovering profound insights into human-computer interaction, decision-making processes, cognitive responses to technology, and enhancement of user experiences. As the field progresses, researchers are increasingly exploring innovative methods such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and eye-tracking to unravel the complex mechanisms underlying human cognition in the digital age. By delving into the neurobiological basis of technology-mediated interactions, NeuroIS presents opportunities for designing more intuitive, efficient, and user-centric systems. With numerous uncharted research paths ahead, the future of NeuroIS looks promising, signaling a potential shift in how we understand and utilize information systems to impact human behaviors and decisions.

Keywords: NeuroIS; Information Systems (IS); Human-Computer Interaction (HCI); Neuroscience; State-of-the-art.

1- Introduction

The utilization of cognitive neuroscience in information management represents a novel research approach within the realm of information systems, which has emerged in recent years under the banner of neural information systems, or NeuroIS. NeuroIS, a subfield of information systems (IS), harnesses neuroscience and neurophysiological tools and knowledge to gain deeper insights into information systems phenomena [1]. It serves as a crucial bridge between neuroscience, psychology, and information systems research, facilitating the examination of the impact of new technology and its utilization. The research findings derived from this approach can provide valuable guidance for the development of new information system designs and applications [2].

NeuroIS endeavors to comprehend the internal processes that underlie human behavior within the context of information systems by leveraging theories and tools from neuroscience and related disciplines. Its overarching goal is to make significant contributions, such as informing the design of IT artifacts, introducing a biological level of analysis as a mediator between IT artifact and IT behavior, elucidating the theoretical mechanisms that underlie the influence of IT artifacts on IT behavior, and offering additional avenues for the evaluation of IT artifacts [3]. Although the field is still considered nascent within the domain of information systems, further endeavors are imperative to advance it from both theoretical and methodological standpoints.

✉ **Mohammad Mehraeen**
mehraeen@um.ac.ir

This paper provides a comprehensive overview of the genesis and current status of NeuroIS, commencing with the definition of NeuroIS and delving into its developmental trajectory. Section 2 outlines the current state of development of NeuroIS and literature background. While Section 3 expounds upon the Research Methodology. Section 4 presents Number of the NeuroIS related publications. Section 5 expounds Contributions of neuroscience to IS research. Section 6 categorizes neuroscience theories in NeuroIS. Section 7 introduces the thematic orientation of NeuroIS research. Section 8 presents Analysis of Methodological of NeuroIS Researches. Section 9 outlines Analysis of Areas of NeuroIS Research. Section 10 delves into Disruptive technologies and Tools in NeuroIS research. Section 11 outlines the conclusion, summarizes the development of this paper and NeuroIS.

2- Literature Background

2-1- The Origins and Development of NeuroIS

NeuroIS (Neuro-Information-Systems), is an interdisciplinary field within information systems that utilizes neuroscience and neurophysiological tools and theories to gain a deeper understanding of the development, adoption, and impact of information and communication technologies.

The concept of applying cognitive neuroscience approaches in IS research was first introduced at the 2007 International Conference on Information Systems (ICIS), and the term "NeuroIS" was coined by Dimoka et al. (2007).

NeuroIS aims to achieve two main goals. Firstly, it seeks to contribute to an advanced theoretical understanding of the design, development, use, and impact of information and communication technologies. Secondly, it aims to contribute to the design and development of IT systems that have a positive effect on practical outcome variables such as health, well-being, satisfaction, adoption, and productivity.

Since 2009, an annual academic conference has been organized to present research and development projects at the intersection of IS and neurobiology. The goal of this event is to facilitate the successful development of the NeuroIS field.

Topics explored in NeuroIS research include conceptual and empirical works, as well as theoretical and design science research. It encompasses a wide range of neuroscience and neurophysiological tools, including techniques such as functional magnetic resonance imaging (FMRI), electroencephalography (EEG), hormone assessments, skin conductance and heart rate measurement, eye-tracking, and facial electromyography. Additionally, it is anticipated that quantitative and molecular genetics will play a role in future NeuroIS research [4]. Over the years, NeuroIS has gained momentum and recognition, with an increasing number of studies and applications emerging across different domains.

ffering new insights and opportunities for understanding human behavior and cognition in the context of information systems. Figure1 shows the timeline of the emergence and development of NeuroIS.

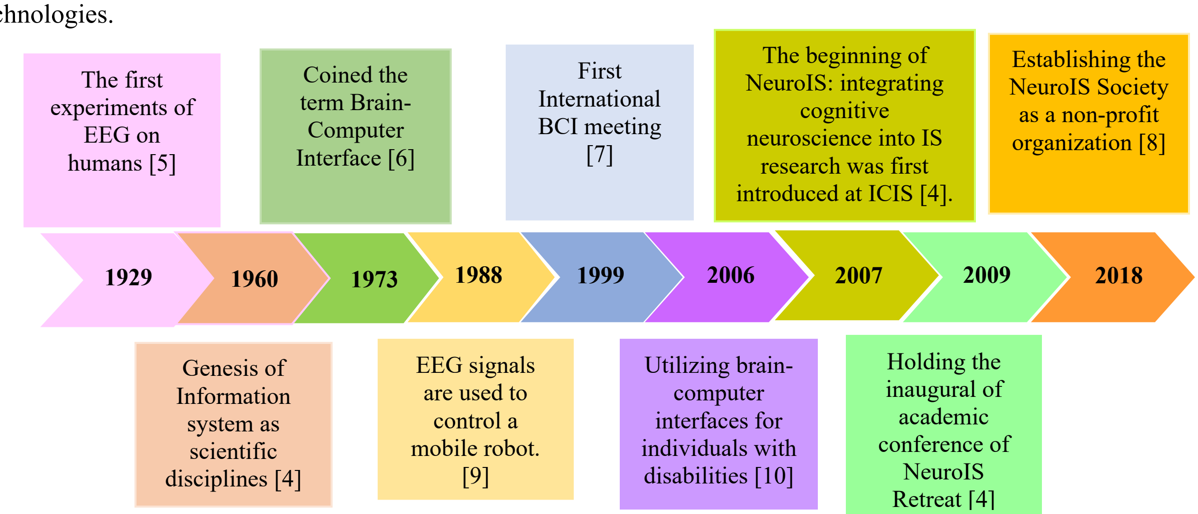

Figure 1.Timeline of the genesis and development of NeuroIS (Source: authors)

2-2- The Integration of Neuroscience and Information Systems

IS research aims to describe, explain, predict, and design IT phenomena, drawing on knowledge and methods from diverse reference disciplines. This interdisciplinary influence allows IS research to address four levels of analysis: individual, group, organization, and society [11]. Various research methods, including laboratory experiments, surveys, case studies, action research, design science methods, and mathematical methods, have been employed in IS research. There is a need for the IS field to update and strengthen its investigative approaches to continue progressing. For example, knowledge of the neurobiology of learning, memory, and attention can inform the design of user interfaces. As many constructs in IS research are associated with human information and decision behavior, insights from neuropsychology and cognitive neuroscience can inform the study of a wide range of IS phenomena.

Several research fields and disciplines are important references for NeuroIS research. These fields include biology and medicine, as well as engineering and computer science. Insights from biology and medicine tend to contribute more to theoretical research than design research. Additionally, insights from engineering and computer science tend to contribute more to design research than theoretical research [1]. From an IS perspective, disciplines such as neuropsychology, cognitive neuroscience, neuroeconomics, decision and social neuroscience are considered fundamental research, while neuromarketing and consumer neuroscience, neuroergonomics, affective computing, and brain-computer interaction are more often associated with applied research. As technology continues to advance, the potential applications of NeuroIS are expected to expand, making it an exciting and dynamic field of study. Figure 2 distinguishes between theory-focused and design-focused research, as well as fundamental and applied research [11].

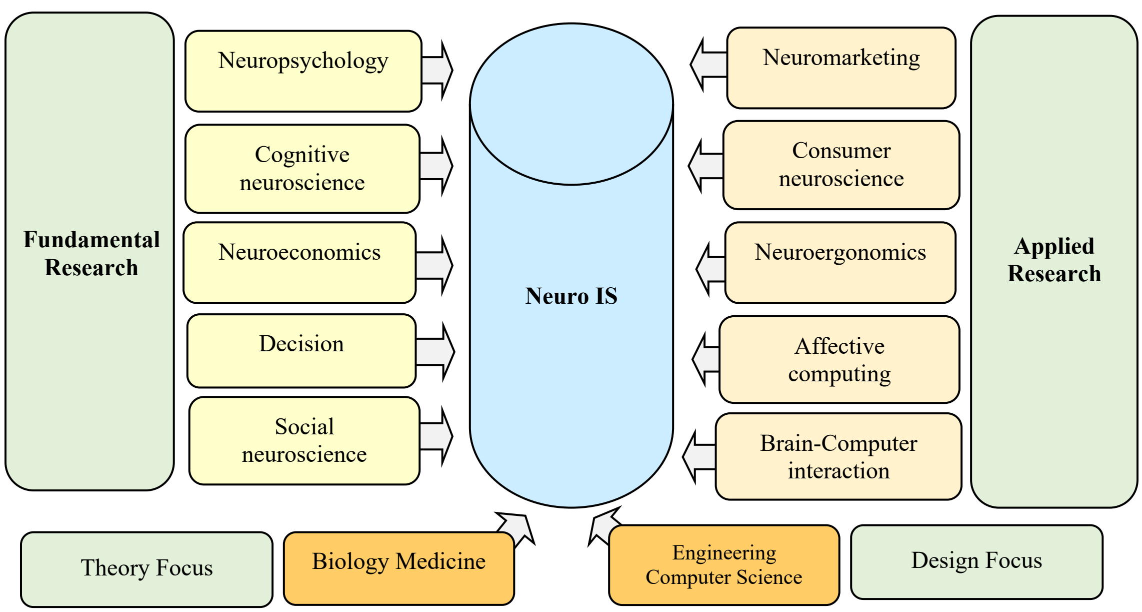

Figure 2. Reference disciplines of NeuroIS (Adapted from: [11])

As the NeuroIS field matures, it is expected that new reference disciplines will emerge, some of the existing reference disciplines will become more important for IS research, and NeuroIS itself will contribute knowledge to these reference disciplines.

2-3- Applications of NeuroIS

Some potential applications of NeuroIS include improving user interfaces for software systems, enhancing the design of online advertisements to better capture attention and engagement, and optimizing the layout and content of websites to maximize user satisfaction and task performance. Additionally, NeuroIS can be used to develop more effective training programs and decision support systems by understanding how users process information and make decisions (Table 1).

Table 1. Applications neuroscience in information systems

Applications	***Attributes***
User Experience Research and designing user interfaces	Using neuroimaging techniques such as fMRI (functional Magnetic Resonance Imaging) and EEG (Electroencephalography) to study users' cognitive and emotional responses to different interfaces and design elements. This can help in designing more user-friendly and effective systems [12].
E-Commerce and designing of online advertisements	Neuromarketing: Applying neuroimaging and psychophysiological techniques to understand consumers' responses to marketing stimuli such as advertisements, product designs, and branding. This can provide insights into consumer preferences and decision-making processes [13].
Information Security	Studying the neural correlates of security threats and decision-making to develop more effective security measures and policies. This can help in designing systems that are more resistant to human error and manipulation [14][15].
Healthcare Systems	Using neuroimaging and physiological monitoring to improve the design of healthcare systems, such as electronic health records and medical devices, to enhance patient safety and user experience [16].
Education and Training	Applying neuroscientific principles to develop more effective e-learning systems and training programs. This can help in optimizing the delivery of educational content and improving learning outcomes [17].
Financial Decision Making	Studying the neural mechanisms underlying financial decision-making to develop better decision support systems and tools for investors and financial professionals [18].

3- Research Methodology

This paper presents a thorough and unified analysis of the current status of NeuroIS. Our approach is rooted in the latest advancements in the field, aiming to uncover ongoing scholarly discussions, examine key findings, and outline future directions. In contrast to conventional literature reviews, the Systematic Review of Literature (SRL) offers numerous advantages, such as mitigating bias and ensuring transparency and reproducibility [19].
The main objective of this study is to provide a comprehensive and coherent overview of NeuroIS, to provide insight into its practical application, and to evaluate factors influencing its adoption in IS research. According to the research process (Figure 3), a search was first conducted in the Elsevier Scopus database to identify relevant studies. Inclusion criteria included articles written in English, and the review period between 2000 and 2024 included articles, conference papers, book chapters, and reviews. The keyword “NeuroIS” was searched, and the title, keyword, and abstract fields. Then articles full text were examined and 244 articles were extracted from the Scopus database and discussed and analyzed.

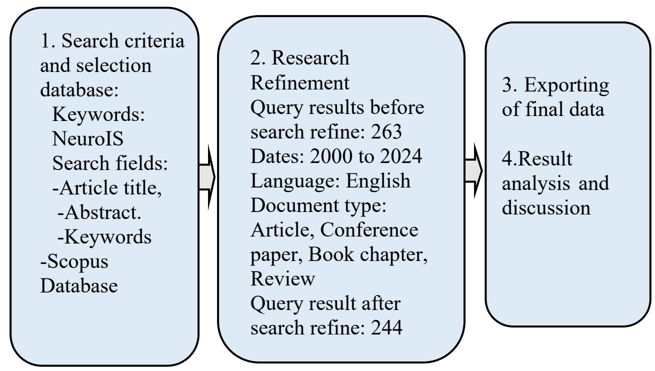

Figure 3. Framework research methodology (Source: [19]).

4- Number of the NeuroIS Related Publications

Scopus is a web-based multidisciplinary literature database. It is the world's largest comprehensive academic information resource covering various disciplines. It includes core academic journals influential in fields like natural sciences, engineering technology, and biomedicine. Thus, we analyze the development of NeuroIS by counting the NeuroIS-related publications in this database. As of February 17, 2024, 263 NeuroIS-related publications have been found. Figure 4 shows the publication numbers over the years, revealing four stages of NeuroIS development: Embryonic Stage, Primary Stage, Ebb Stage, and Development Stage.

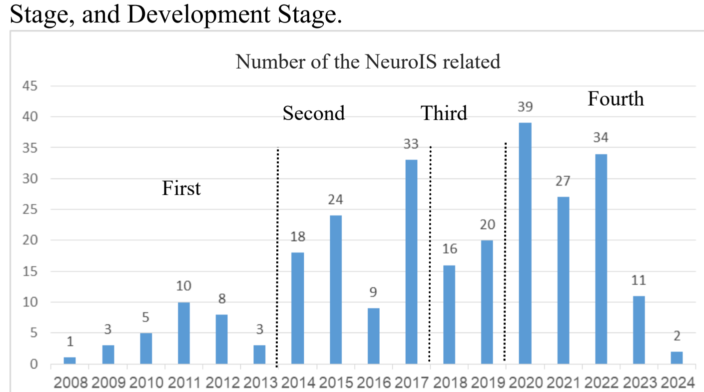

Figure 4. Publications in Scopus statistics chart

The embryonic stage includes the emergence of NeuroIS in 2007 and the annual holding of NeuroIS conferences since

2009. In the initial stage, we see the growth of publications in the field of NeuroIS. In the decline stage, the number of publications in the field of NeuroIS has decreased, but in the growth stage and using disruptive technologies in this field, we again see the growth of publications and innovation in published studies and research in the field of NeuroIS.

5- Contributions of Neuroscience to IS Research

NeuroIS has various applications across different domains and focuses on various research areas such as technology adoption, mental workload, website design, virtual worlds, and emotions in human-computer interaction, IT security, and other related topics. The ways in which neuroscience contributes to IS research are summarized in Figure 5. [4]. See Table 2. (In this section, the review articles that discussed and expressed the general definition of neurois were removed and only 221 articles were reviewed.)
The review of studies shows (Figure 6**)** that the greatest number of articles (34 articles) were published in relation to contribution 9, which focuses on "Using real-time information about the user's biological state in information systems research and design of biofeedback systems," while the fewest articles (15 articles) were published in relation to contribution 4, which pertains to "Brain activity and other biological responses can inform the evaluation of IT tools. “It’s evident that contribution 9 has garnered significant attention within the academic community, likely due to the growing interest in leveraging real-time biological data for the advancement of information systems and biofeedback technology. On the other hand, contribution 4, despite its relevance in evaluating IT tools using biological responses, seems to have received comparatively less focus. This discrepancy in article publication numbers underscores the varying degrees of emphasis placed on different aspects of biological state utilization within the realm of information systems research and design.

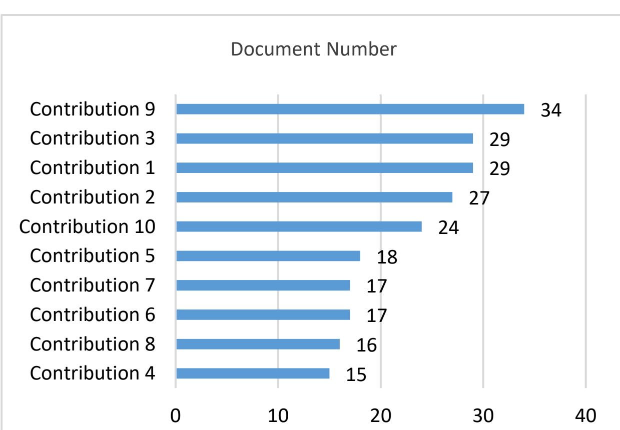

Figure 6. Articles published based on neuroscience contributions to IS research (N=221)

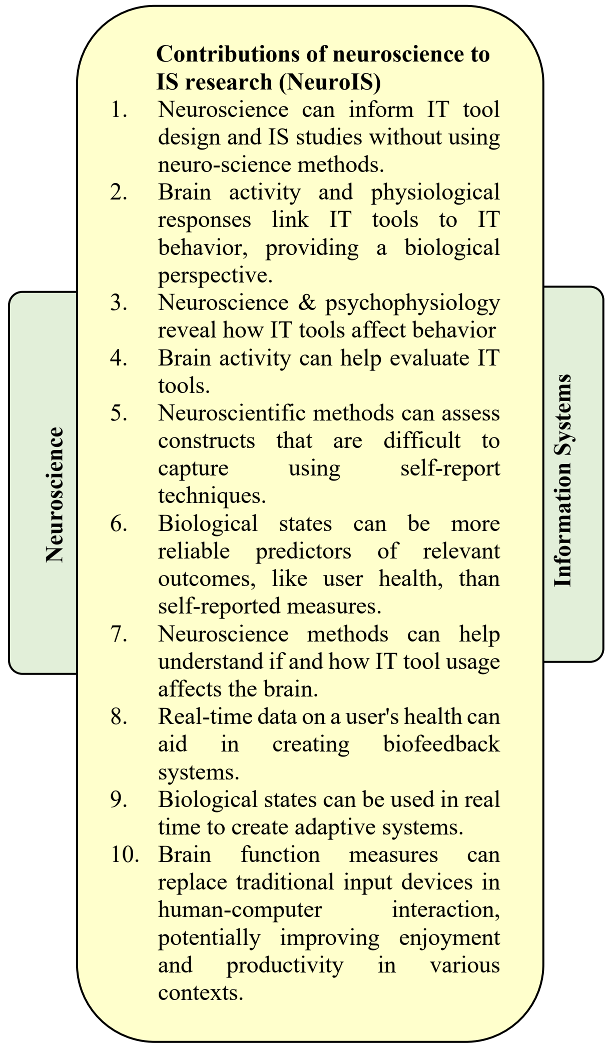

Figure 5. Contributions of neuroscience to IS research (Adapted from: [11])

Table 2. Contributions of neuroscience to IS research

Cont ribut ions	***Attributes***	***Major themes/ application***	***Studies (N)***

Contribution 1	Neuroscience theories and literature play a crucial role in informing design decisions and can contribute in various specific ways. They can enhance the motivation for future behavioral IS studies, aid in the design of behavioral experiments and other forms of empirical inquiry, provide support for behavioral conclusions, and challenge existing assumptions and theories.	design decisions/ design and development of an IT artifact- design of behavioral experiments- theory development/test and design-oriented works	29
Contribution 2	The use of neuroscience and psychophysiological methods provides a deeper understanding of the impact of IT artifacts and introduces a new level of analysis in IS research by considering individuals' biological systems alongside the traditional levels of analysis.	brain activity patterns- biological systems / actual purchase decisions	27
Contribution 3	By studying brain activity and physiological responses, researchers can gain insights into the cognitive processes involved in using IT tools and how they impact decision-making, attention, and problem-solving. These methods can provide a more nuanced understanding of the ways in which IT tools shape behavior and inform the development of more effective and user-friendly technologies.	IT behavior/ the trustworthiness of the online shop- increased number of purchases	29
Contribution 4	Monitoring brain activity and using new software can give insight into user experience and cognitive load. Tracking physiological responses like heart rate and skin conductance can assess the impact of IT tools on stress and well-being. Incorporating these measures can help organizations understand how IT tools affect users and make informed decisions.	design of IT artifacts/ trust- IT artifact evaluation	15
Contribution 5	Neuroscience methods offer a more precise way to assess automaticity in IT use, leading to a deeper understanding of cognitive processes and behaviors. By measuring neural activity and physiological responses, we can uncover unconscious patterns of IT use, providing comprehensive insights into the impact of technology on the brain and behavior.	Automaticity/ affect reliability of data	18
Contribution 6	Biological measures can be objectively quantified and monitored over time, providing a more reliable and consistent source of data for predicting relevant outcomes.	Prediction/ hormone assessments- technostress	17
Contribution 7	Studying brain activity during IT tasks reveals insights into cognitive processes and neural mechanisms in technology use. Neuroscientific methods offer valuable data on IT' is long-term impact on brain structure and function.	alters the brain/ addiction- multitasking performance	17
Contribution 8	By leveraging real-time physiological and biochemical information, we can develop personalized interventions and solutions that cater to individual needs, ultimately leading to improved overall performance and quality of life.	neuroadaptive system / design adaptive systems- Design science research	16
Contribution 9	Biofeedback systems offer insights into a person's physical responses, allowing for personalized interventions to reduce stress and improve well-being. Using real-time data, they provide tailored strategies for managing stress, enhancing mental clarity, and optimizing performance in life.	Biofeedback systems/consciously control the physiological indicator	34
Contribution 10	This tech can change how we use computers, making it more intuitive and natural. It can eliminate the need for physical input devices, allowing for faster interaction and enhancing how work and play.	Brain-computer interfacing (BCI) human-computer interaction (HCI)/ video games- enterprise systems- commercial contexts- business domain	24

6- Classification of Neuroscience Theories in NeuroIS

The definition of theory in neuroscience is complex and varies among scholars. Gregor et al. (2014) outlines five different forms of theory, including analysis, explanation, prediction, explaining and predicting, and design and action [20]. Riedl & Léger (2016) propose a taxonomy of neuroscience theories based on three categories: analysis, explanation, and design and action. They argue that reference theories from neuroscience and related disciplines can be classified into one of these categories, although overlapping can occur. The three theory types are interdependent, with explanation relying on analysis, and design and action benefiting from explanation. The authors also discuss the importance of theoretical neuroscience knowledge for NeuroIS scholars [4].

The review of published articles indicates that 55% of NeuroIS articles have utilized the Explanation theory, 29% have incorporated the Design and Action theory, and 16% have applied the Analysis theory (Figure7).

The Explanation theory is the most commonly utilized theory in NeuroIS research, suggesting that researchers are primarily focused on understanding the underlying mechanisms and processes of neurological phenomena in information systems. The Design and Action theory, which focuses on the practical application of neuroscientific findings in designing and implementing information systems, is also a popular choice among researchers. The Analysis theory, which emphasizes the use of neuroscientific methods to analyze and interpret data in information systems research, is less commonly used but still present in a significant number of articles.

Overall, these findings suggest that NeuroIS researchers are interested in a wide range of theoretical approaches and methodologies, reflecting the interdisciplinary nature of the field. By incorporating multiple theories and perspectives, researchers can gain a more comprehensive understanding of how neuroscience can inform and improve information systems design and implementation. See Table 3 and Figure 7. (In this section, the review articles that discussed and expressed the general definition of neurois were removed and only 221 articles were reviewed.)

Table 3. Theory type in NeuroIS

Theory type	***Attributes***	***Studies***
NeuroIS Theory- Analysis	Neuroscience theories in the analysis category provide descriptions and classifications of neuroscience phenomena, including the fundamentals about the anatomy of the nervous system, such as the structure and function of neurons and the organization of the human brain into four lobes. This descriptive knowledge is important for gaining insight into the hierarchical relationships between various anatomical regions from a NeuroIS perspective [4].	35
NeuroIS Theory - Explanation	In recent years, it has become clear that the brain functions as a network with many connections. Both gut feelings (emotion) and logical thinking have distinct neural structures in the human brain. Certain mental processes rely on activity in specific brain regions, and impairments in these areas can lead to cognitive, emotional, or behavioral problems. NeuroIS scholars must understand neuroscience terminology, brain region interconnections, and the roles of specific brain areas and nervous system components. This knowledge is essential for understanding cognitive, emotional, and behavioral functions, as well as for developing theoretical knowledge. Another important area of theoretical knowledge is the basal ganglia, which are subcortical brain regions that are important for functions like motor control, reward processing, learning, and motivation. Contemporary NeuroIS research often does not incorporate neuroscience theories, but applying these theories can lead to creative insights and provide a framework for decision making and the influence of emotion on it [4].	121
NeuroIS Theory – Design and Action	Neuroscience theories are used to create guidelines for building neuro-adaptive systems. Design science research in the information systems field focuses on developing theories for creating IT artifacts with specific purposes. One major application strategy involves integrating neuroscience tools into IT artifacts. The goal is to develop prescriptions for designing neuro-adaptive systems that can be used by engineers and researchers for developing saleable systems and prototypes [21].	65

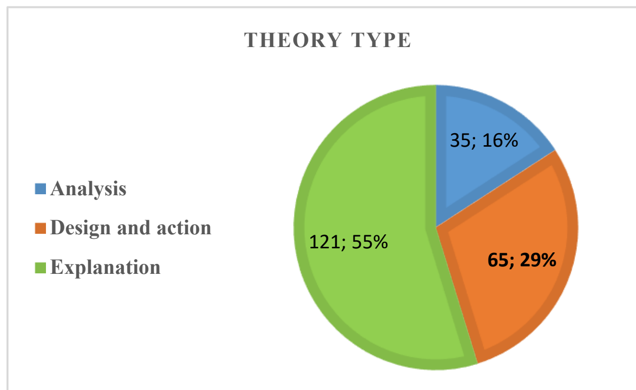

Figure 7. Articles published based on theory type in NeuroIS (N=221)

7- The Direction of the Primary Subjects (Constructs) of NeuroIS Research

A study of theoretical research by, Pavlou, Davis and Dimoka (2007) revealed that NeuroIS candidate topics can be categorized into four groups. This list adds to existing literature on NeuroIS topics and emphasizes the potential of IS and neuroscience research in various areas. The structures are grouped into four categories as follows (Table 4) [22]. Cognitive processes, emotional processes, social processes, and decision-making processes. These factors reflect how individuals comprehend, feel about, engage with others, and make decisions regarding objective things. Figure 8 illustrates the predominant thematic focus among the 244 papers analyzed, with a notable emphasis on cognitive processes (105 papers, 43%) and emotional processes (60 papers, 25%). In contrast, social processes

(45 papers, 18%) and decision-making processes (34 papers, 14%) have received comparatively less attention. It is noteworthy that cognition and emotion play integral roles in both social interactions and decision-making. These findings suggest that the NeuroIS community has primarily delved into the fundamental processes while leaving a gap in exploring their implications for social dynamics and decision-making paradigms. Moving forward, future research in the field of NeuroIS could benefit from a more balanced exploration of all four organism factors to gain a comprehensive understanding of how cognitive, emotional, social, and decision-making processes interact and influence each other within the context of information systems. By bridging the gap between fundamental processes and their implications for social dynamics and decision-making paradigms, researchers can contribute valuable insights that may enhance the design and implementation of information systems to better support human cognition, emotion, social interactions, and decision-making processes.

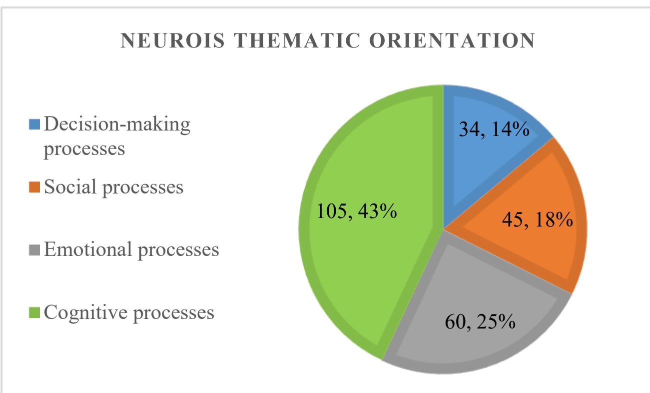

Figure 8. Articles published based on constructs of NeuroIS research (N=244)

8- Analysis of Methodological of NeuroIS Researches

Based on an extensive review of pertinent literature (comprising 244 papers), the research methodologies were meticulously categorized and synthesized, as illustrated in Figure 9. Concerning the research methodologies employed, a significant portion of the papers (136 articles in total) within this study utilized an experimental design, while 21 studies opted for survey methodologies, and 49 papers adopted mixed research methodologies.

It is evident that studies utilizing mixed research methodologies are relatively new, suggesting that mixed research could potentially emerge as a novel trend within the NeuroIS domain. In the realm of mixed studies, Zazon et al. in 2023 employed a mixed-research framework, amalgamating a neuro-based decision support system to stratify cognitive functions into distinct levels aimed at enhancing candidate information during recruitment processes [35]. Their methodology involved evaluating the functional and cognitive proficiencies of 142 adults through assessments of executive functions and intelligence scores. Subsequently, brain signals were analyzed using EEG technology, and machine learning algorithms were leveraged to classify executive functions and intelligence levels.

Table 4. Constructs of NeuroIS research

constructs	***Attributes***	***Topics***
Cognitive processes	NeuroIS research focuses on cognitive processes and their impact on information systems (IS). It encompasses five main areas: enhancing task performance [23], understanding ability to uncover the cognitive neural mechanisms of individuals, particularly in areas such as attention distribution [24], addressing security challenges [14] [15], improving user experience, and using neuroscience to comprehend IS adoption [25] .Researchers use objective tools to overcome biases and gain a better understanding of human-computer interaction.	Information processing, Cognitive effort, Working memory, Multitasking; Automaticity; Habit; Priming; Spatial cognition; Flow
Emotional processes	Emotion is crucial in human experiences; NeuroIS offers new ways to understand emotions. Researchers focus on enhancing user experience [26], integrating emotions into IS design, and exploring emotional processes in IS use. Studies cover topics like screen luminance impact on visual fatigue [27], emotion-inducing images for information recall [28], and avatar similarity on emotional regulation [29]. Technostress in IS can negatively affect job satisfaction and organizational commitment. Human emotions are important in IS security and adoption studies, influencing loyalty to a website [30].	Pleasure/enjoyment, Displeasure, Happiness, Sadness, Anxiety, Disgust, Fear, Anger, Emotional processing
Social processes	NeuroIS research has identified four key constructs related to social processes: trust, inspiration, distrust, and mentalizing. Trust in IS and IS adoption have been the primary focus within this category [31] [32].	Social cognition, Trust, Cooperation, Competition, Theory of mind
Decision-making processes	New technologies such as data analytics can be helpful for decision makers, but they will not completely replace traditional decision-making processes. There is a lack of research on information systems security and trust. NeuroIS researchers have used EEG and other methods to study	Calculation, Uncertainty, Risk, ambiguity, Loss, Rewards and utility, Intentions,

	individual decision-making and predict security behavior [33], as well as the relationship between decision-making and trust. For instance, studies have found that product ratings and sales volume can impact consumers' trust in products [34]	Task intentions, Motor intentions

Similarly, Reßing et al. (2022) conducted a study on mind wandering in the context of digital technology utilization [36]. Their research entailed an experimental approach integrating EEG, eye-tracking, questionnaires, and performance metrics to evaluate mind wandering occurrences. The study encompassed the collection of quantitative data through self-reported assessments of mind-wandering frequency and duration, alongside objective appraisals of task performance. Additionally, qualitative data were gathered through semi-structured interviews with participants to offer a more comprehensive understanding of their experiences with mind wandering during digital technology usage.

Moreover, 38 studies centered on literature reviews were undertaken for this research endeavor. These literature reviews, characterized by their substantial citations and influence, partly reflect the evolving emphasis within the NeuroIS domain on embracing and integrating such research methodologies in recent years.

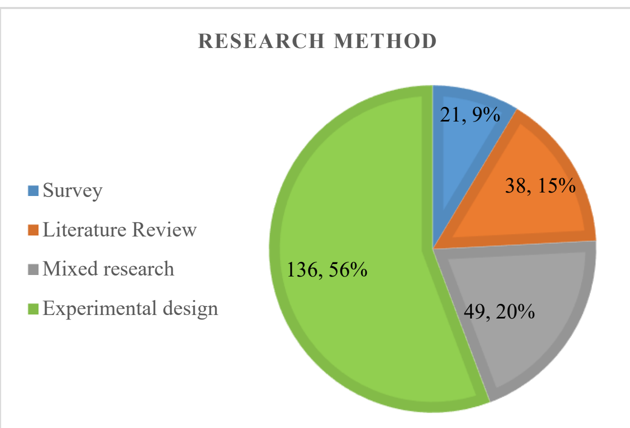

Figure 9. Methodology of published researches in NeuroIS fields (N=244)

9- Analysis of Areas of NeuroIS Researches

Vom Brocke et al. (2020) identified key domains in NeuroIS such as IS design, IS utilization, emotion research, and neuro-adaptive systems [36]. It is crucial for NeuroIS to enhance its impact on practical situations. Following calls for addressing societal and economic challenges in the IS domain, NeuroIS should increase its involvement to address such issues more directly. NeuroIS research should demonstrate how utilizing neuroscience knowledge and methods can offer unique insights [38].

9-1- Information Systems Design (IS Design)

Significant opportunities exist for new research in the synergy between NeuroIS and design [36]. Neuroscience research informs cognitive and affective functions in design processes. It explores problem structuring, novelty production, refinement management, and consensus achievement. Future NeuroIS research aims to enhance IS design and evaluation through neurophysiological insights. Key challenges include understanding complex problems, defining good artifacts, and exploring diverse design approaches. Evaluating includes defining goodness criteria, selecting evaluation methods, and analyzing results to define contributions and evaluate user experience [36]. Contributions to design artifacts and design theory are essential. Integrating NeuroIS with DSR can inform the design of IS artifacts and build neuro-adaptive IS artifacts. Neuroscience can inform IT artifact design and evaluation without using neuroscience methods. Biological processes can design adaptive systems for positive outcomes. Biofeedback systems can help users control physiological indicators for better outcomes. Electrophysiological brain function measures can replace input devices in human-computer interaction for improved outcomes [4].

9-2- Information Systems Use (IS Use)

Research on the negative consequences of digital communication and Internet use is crucial. Normal interpersonal communication could diminish rapidly due to excessive IT use. Smart devices, while enhancing our lives, can also hinder social interactions and productivity [36]. Cyber security, where time pressure is significant, is one area affected. Overuse of IT harms face-to-face communication and social connections [39]. Despite evidence of negative impacts, stakeholders overlook well-being concerns. NeuroIS research can guide discussions on mitigating these effects. IS community plays a vital role in promoting healthy communication amidst technological advancements. NeuroIS can address key research questions to improve understanding and mitigate adverse effects of digital communication devices. NeuroIS research can delve into the neurological processes involved in achieving communication goals. Can digital devices mimic non-verbal cues effectively? Does excessive digital communication hinder social development? Emojis in digital communication may not fully replace real emotions [40].

9-3- Emotion Research

It's crucial to improve communication by defining emotion-related concepts concisely. NeuroIS, as a dynamic field, can redefine emotion more effectively than traditional emotion research. Walla (2018) provides a comprehensive understanding on how cognitive processing (e.g. language) is separate from affective processing that can lead to emotions [39]. Emotions are expressed through measurable behaviors, such as facial expressions, reflecting underlying affective processes. Objective measures are essential to understand the neural activity that drives behavioral responses in using IT systems. Emotion research in NeuroIS faces challenges in integrating self-report measures with physiological responses to predict human behavior accurately. The interplay of preference, technology acceptance, and affective processes underscores the importance of a multi-method approach in research [36].

9-4- Neuro-Adaptive Systems

Neuro-adaptive systems can enhance user experience by responding to their emotional and cognitive states. These systems, like biofeedback bracelets, use body data to adjust smartphone applications. Research on neuro-adaptive systems emphasizes the importance of considering affective computing literature. These systems aim to improve human-computer interaction, potentially benefiting various aspects of society. They could act as personal assistants for healthier lifestyles and contribute to evidence-based medicine. Despite their research potential, their practical implications are not well-documented in academic literature productivity [36].
Figure 10 displays the main areas of focus from the analysis of 244 papers. Among these, 46% of the articles, totaling 112, focus on the utilization of information systems, making it the most extensive domain in NeuroIS research. Information systems design follows closely with 59 articles (24%), emotions with 41 articles (17%), and adaptive-neural systems with 30 articles (13%).The extensive body of work in NeuroIS highlights a significant focus on information systems. This exploration underscores the crucial role of information systems in various contexts. The research emphasizes the complexities of utilizing information systems and the importance of designing efficient, effective, and user-friendly systems. NeuroIS studies on emotions and adaptive-neural systems demonstrate a comprehensive approach to advancing knowledge in these areas.

10- Disruptive Technologies and Tools in NeuroIS Research

There are several tools and Disruptive technologies that are commonly used in NeuroIS research to study the intersection of neuroscience and information systems. Disruptive technologies are innovative technologies that fundamentally change the way things are done, often leading to the disruption of existing industries or practices.

In the field of NeuroIS research, several disruptive technologies have been used to advance our understanding of how the brain interacts with information systems. These disruptive technologies are transforming the field of NeuroIS research by providing new ways to study the brain's interaction with information systems and technologies. They offer exciting opportunities for researchers to explore the complex relationship between the brain, behavior, and technology in innovative and impactful ways. Some examples of disruptive technologies and key tools utilized in NeuroIS research are outlined in Table 5 and Figure 11.

Table 5: Disruptive technologies in NeuroIS research

Technology	***Attributes***
Brain-Computer Interfaces (BCIs)	BCIs are devices that enable direct communication between the brain and external devices, such as computers or prosthetic limbs. In NeuroIS research, BCIs are used to study how users can control information systems using their brain activity. (Examples: [41] [42]).
Virtual Reality (VR) and Augmented Reality (AR)	VR and AR technologies create immersive environments that can be used to study user interactions with information systems in a more realistic and engaging way. These technologies have the potential to revolutionize the way we study user behavior and cognition in the context of information systems. (Examples: [43] [44]).
Wearable Devices	Wearable devices such as smart watches, fitness trackers, and EEG headsets can collect real-time data on users' physiological responses and brain activity. These devices are increasingly being used in NeuroIS research to study user engagement, emotions, and cognitive processes. (Examples: [45] [46] [47] [48] [49]).
Artificial Intelligence (AI) and Machine Learning	AI and machine learning algorithms are used in NeuroIS research to analyze large datasets of brain activity and behavioral data. These technologies can help researchers identify patterns and relationships in the data that may not be apparent through traditional analysis methods. (Examples: [50] [51]).
Robotics	Robotics technology can be used in NeuroIS research to create interactive systems that respond to users' brain activity or emotional states. Robots can be programmed to adapt their behavior based on the user's cognitive and emotional responses, leading to more personalized and engaging interactions. (Examples: [2] [52])
Neurofeedback	Neurofeedback is a disruptive technology that uses real-time brain activity data to provide feedback to users, allowing them to learn to control their brain activity. In NeuroIS research, Neurofeedback can be used to study how users can improve their cognitive performance and well-being through brain training exercises. (Examples: [35] [53]).

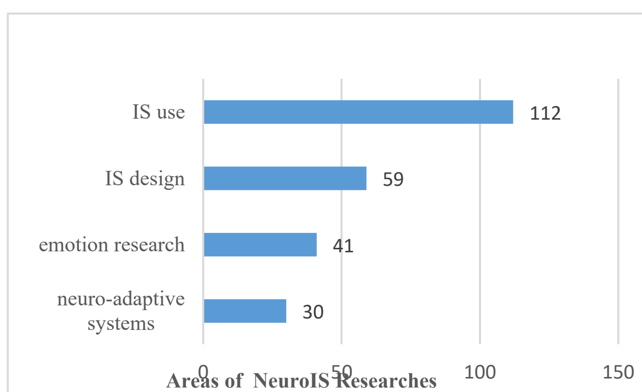

Figure 10. Articles published based on Areas of NeuroIS Researches (N=244)

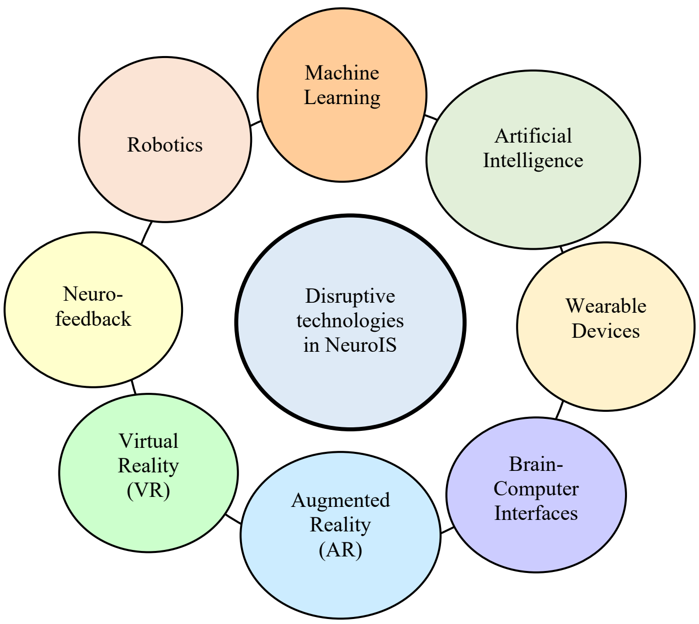

Figure 11. Disruptive technologies in NeuroIS research (Source: authors)

Table 6: key Tools in NeuroIS research

Tools	***Attributes***
Functional Magnetic Resonance Imaging (fMRI)	FMRI is a neuroimaging technique that measures brain activity by detecting changes in blood flow. It is commonly used in NeuroIS research to study how the brain responds to different information systems and technologies. (Examples: [54] [55]).
Electroencephalography (EEG)	EEG is a non-invasive technique that measures electrical activity in the brain. It is often used in NeuroIS research to study cognitive processes such as attention, memory, and decision-making. (Examples: [56] [57] [58]).
Event-related potential (ERP)	ERP is a method used in neuroscience and neuroimaging to measure brain activity in response to specific events or stimuli. By measuring brain activity in real-time, researchers can better understand cognitive processes, attention, memory, and emotional responses during information processing tasks. (Examples: [59] [60]).
Eye-tracking (ET)	Eye-tracking technology is used to monitor and record eye movements and gaze patterns. It is frequently used in NeuroIS research to study how users interact with information systems and websites. (Examples: [61] [62] [63]).
Eye-fixation related potential (EFRP)	EFRP studies brain activity when eyes fixate on visual stimuli. In NeuroIS, EFRP explores how brain processes visuals and links to cognitive/behavioral responses. Researchers use EFRP to understand how people perceive/process visual stimuli, like websites, ads, or interfaces, to improve design for better user experience. (Examples: [64] [65]).
Galvanic Skin Response (GSR)	GSR measures changes in skin conductance, which can be an indicator of emotional arousal and stress. It is often used in NeuroIS research to study user emotions and reactions to information systems. (Examples: [66] [67]).
Magneto encephalography (MEG)	MEG is a neuroimaging technique that measures magnetic fields produced by the brain's electrical activity. It provides high temporal and spatial resolution, making it useful for studying fast neural processes related to technology use. (Examples: [68] [69].
Functional near-infrared spectroscopy (fNIRS)	FNIRS is a non-invasive technique that measures changes in blood oxygenation in the brain, providing information about brain activity during cognitive tasks. It is often used in studies of attention, memory, and decision-making in relation to technology. (Examples: [13] [70]).
Electrodermal activity (EDA)	Electrodermal activity (EDA) measures skin conductance changes in response to emotions or stress. In NeuroIS, EDA studies emotional and cognitive responses to technology. Researchers use EDA to assess user arousal and engagement with digital interfaces, providing insights into user experience and technology engagement. (Examples: [71] [72]).
Automatic Facial Expression Analysis (AFEA)	AFEA involves the use of computer algorithms to detect and analyze facial expressions in real-time, allowing researchers to understand how individuals react to various stimuli in a more objective and reliable manner. (Examples: [73] [74]).
Heart Rate Variability (HRV)	HRV measures the variation in time intervals between heartbeats, reflecting the autonomic nervous system's activity. It is used to study stress, arousal, and emotional responses to technology. (Examples: [46] [47] [48] [75]).
Electrocardiogram (ECG or EKG)	ECG is a tool used to measure the electrical activity of the heart. ECG provides information about heart rate, heart rate variability, and other cardiac parameters that can reflect the emotional and cognitive states of users during their interactions with technology. (Examples: [76] [77]).
Genetics	Genetics research in NeuroIS can also help identify genetic markers that may predict an individual's response to different neurotechnologies, such as brain-computer interfaces or neurofeedback. This personalized approach to neurotechnology can enhance the effectiveness of interventions and improve outcomes for individuals with neurological conditions. (Examples: [78] [79]).
Experimental design and statistical analysis	Rigorous experimental design and statistical analysis are essential tools in NeuroIS research to ensure the validity and reliability of research findings. (Examples: [80] [81])).

NeuroIS software tools	There are also specialized software tools and platforms available for conducting NeuroIS research, such as BrainVision Analyzer, EEGLAB, and NeuroPype. These tools help researchers analyze and visualize brain activity data and integrate it with behavioral data from information systems. (Examples: [82] [83] [84]).

Based on our sample comprising 244 instances, Figure 12 illustrates that Electroencephalography (EEG) is the predominant tool utilized in NeuroIS research, accounting for 42 papers or 29%. This is followed by eye-tracking (ET) and Functional Magnetic Resonance Imaging (FMRI), each represented in 39 papers, equivalent to 16%, and Heart Rate Variability (HRV) with 33 papers, constituting 14% of the total. Additionally, the assessment of Functional near-infrared spectroscopy (fNIRS) is observed in 11 papers (5%), Electrodermal activity (EDA) and Event-related potential (ERP) each appear in 9 papers, representing 4% each. Other methodologies and tools applied in NeuroIS encompass Electrocardiogram (ECG or EKG), Automatic Facial Expression Analysis (AFEA), Genetics, Magneto encephalography (MEG), Galvanic Skin Response (GSR), and Eye-fixation related potential (EFRP).In terms of future research directions, it would be beneficial to explore the integration of multiple neuroimaging techniques to gain a more comprehensive understanding of brain activity in the context of information systems. Moreover, investigating the combination of physiological measures with neuroimaging data could provide valuable insights into the cognitive processes underlying human-computer interactions. Additionally, exploring the potential applications of emerging technologies such as virtual reality and brain-computer interfaces in NeuroIS research could open up new avenues for studying the interplay between technology and the human brain. Overall, continued advancements in neuroimaging technology and interdisciplinary collaborations are crucial for advancing the field of NeuroIS and unlocking its full potential in understanding human cognition and behavior in the digital age**.**

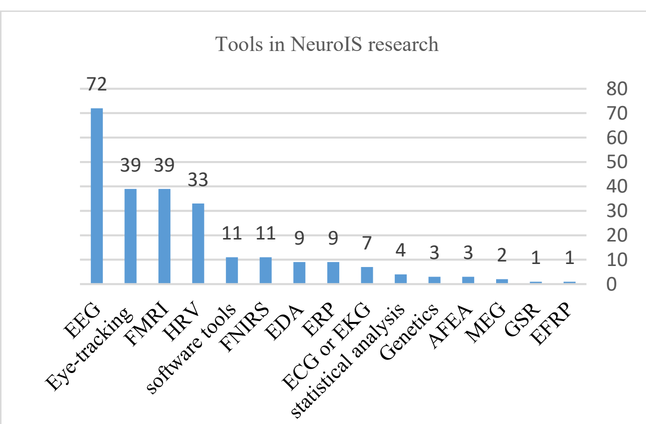

Figure 12. Articles published based on Areas of NeuroIS Researches (N=244)

11- Conclusions

NeuroIS is an emerging field with a limited number of studies. This paper aims to provide a state-of-the-art overview of NeuroIS by focusing on 244 articles extracted from the Scopus database. It discusses the development and application prospects of NeuroIS, covering its origins, the integration of neuroscience and information systems, relevant publications, contributions of neuroscience to IS research, thematic orientation of NeuroIS research, methodological analysis of NeuroIS research, areas of NeuroIS research, and disruptive technologies and tools in NeuroIS research. Recent research indicates rapid evolution in NeuroIS, offering valuable insights into the intersection of neuroscience and information systems. This field has the potential to revolutionize user behavior understanding, system design, and decision-making processes, paving the way for innovative applications and advancements in information systems.

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