RESEARCH ARTICLE

INTERSECTIONS OF NEUROSCIENCE AND DESIGN: A SCOPING REVIEW OF NEURODESIGN RESEARCH*

Simge KIRTEKE, Ertan TOY*****

Received: 23.11.2025 - Accepted: 22.01.2026

Kırteke, S., & Toy, E. (2026). Intersections of neuroscience and design: A scoping review of neurodesign research. *Etkileşim*, 17, 238-260.
https://doi.org/10.32739/etkilesim.2025.9.17.xxx

This study complies with research and publication ethics.

Abstract

Today, the use of neuroscience-based measurement tools in design research is gaining importance because they allow for discussing creative processes not only through description but also through measurable variables. Observational and interpretive approaches in design apolications are moving towards an evidence-based framework by examining attention, memory, decision-making, and creativity processes in problem-solving and idea generation more concretely using cognitive neuroscience methods such as fMRI, EEG, and eye-tracking. This study aims to review the literature comprehensively on the use of cognitive neuroscience tools in design, in accordance with the PRISMA-ScR principles. During the search process, data were extracted from the *Scopus* and *Web of Science* databases using the keyword 'neurodesign' for the years 2009-2025. After eliminating duplicate studies, evaluation was performed at the title-abstract and full-text stages using predefined inclusion/exclusion criteria. The studies reviewed were classified according to the tools/techniques used (fMRI, EEG, eye tracking, etc.), sample type (design student/professional designer), task type (idea generation, problem framing, evaluation, prototyping, etc.), and measured cognitive functions (attention, memory, problem solving, creativity). Based on this classification, general trends in the field, conceptual gaps, and recurring methodological choices are discussed; furthermore, feasible suggestions are offered for transferring neuroscience findings into design education and professional practice. In conclusion, the study aims to propose both a methodological roadmap and a theoretical foundation for future neuroscience-based design research.

Keywords: visual design, neuroscience, neurodesign, scoping review, PRISMA-ScR.

* This study was produced from Simge Kırteke's doctoral thesis, which was conducted under the supervision of Assoc. Prof. Dr. Ertan Toy in the Art and Design Doctorate program of Yıldız Technical University, Institute of Social Sciences.

** Research Assistant (PhD), Üsküdar University, Faculty of Communication, İstanbul, Türkiye.
simge.kirteke@uskudar.edu.tr, ORCID: 0000-0003-0621-8177
*** Associate Professor/PhD, Yıldız Technical University, Faculty of Art and Design, İstanbul, Türkiye.
ertantoy@yildiz.edu.tr, ORCID: 0000-0002-7959-7967

ARAŞTIRMA MAKALESİ

NÖROBİLİM VE TASARIMIN KESİŞİM NOKTALARI: NÖROTASARIM ARAŞTIRMASININ KAPSAM İNCELEMESİ*

Simge KIRTEKE, Ertan TOY*****

Gönderim Tarihi: 23.11.2025 – Kabul Tarihi: 22.01.2026

Kırteke, S., & Toy, E. (2026). Intersections of neuroscience and design: A scoping review of neurodesign research. *Etkileşim*, 17, 238-260.
https://doi.org/10.32739/etkilesim.2025.9.17.xxx

Bu çalışma araştırma ve yayın etiğine uygun olarak gerçekleştirilmiştir.

Öz

Günümüzde tasarım araştırmalarında nörobilim temelli ölçüm araçlarının kullanımı, yaratıcı süreçleri yalnızca betimlemekle kalmayıp ölçülebilir değişkenler üzerinden tartışabilmeye imkân verdiği için her geçen gün önem kazanmaktadır. Tasarım uygulamalarında gözlem ve yoruma dayalı yaklaşımlar, fMRI, EEG ve göz izleme gibi bilişsel nörobilim yöntemleriyle problem çözme ve fikir üretmedeki dikkat, bellek, karar verme ve yaratıcılık süreçlerini daha somut inceleyerek kanıta dayalı bir çerçeveye yönelmektedir. Nörotasarım çalışmaları çerçevesinde kapsam analizi yöntemiyle hazırlanan bu çalışma, PRISMA-ScR ilkeleri doğrultusunda, tasarım alanında bilişsel nörobilim araçlarının kullanımına ilişkin literatürü kapsamlı biçimde taramayı amaçlamaktadır. Tarama sürecinde *Scopus* ve *Web of Science* veri tabanlarından 2009-2025 tarihleri kapsamında 'neurodesign' anahtar kelimesi kullanılarak veriler çıkarılmış, önceden belirlenen dahil etme/dışlama ölçütleriyle değerlendirme yapılmıştır. İncelemeye alınan çalışmalar, kullanılan araç/teknik (fMRI, EEG, göz izleme vb.), örneklem türü, görev türü ve ölçülen bilişsel işlevler gibi boyutlarda sınıflandırılmıştır. Bu sınıflandırma üzerinden alanın genel eğilimleri, kavramsal boşlukları ve tekrarlayan yöntemsel tercihleri tartışılmakta; ayrıca nörobilim bulgularının tasarım eğitimine ve profesyonel uygulamaya aktarılabilmesi için uygulanabilir öneriler sunulmaktadır. Sonuç olarak çalışma, gelecekte yürütülecek nörobilim temelli tasarım araştırmaları için hem yöntemsel bir yol haritası hem de kuramsal bir zemin önermeyi hedeflemektedir.

Anahtar Kelimeler: görsel tasarım, nörobilim, nörotasarım, kapsam incelemesi, PRISMA-ScR.

* Bu çalışma Simge Kırteke'nin Yıldız Teknik Üniversitesi Sosyal Bilimler Enstitüsü Sanat ve Tasarım Doktora Programı'nda Doç. Dr. Ertan Toy'un danışmanlığında yürüttüğü doktora tezinden üretilmiştir.

** Araştırma Görevlisi Doktor, Üsküdar Üniversitesi, İletişim Fakültesi, İstanbul, Türkiye.
simge.kirteke@uskudar.edu.tr, ORCID: 0000-0003-0621-8177
*** Doçent Doktor, Yıldız Teknik Üniversitesi, Sanat ve Tasarım Fakültesi, İstanbul, Türkiye.
ertantoy@yildiz.edu.tr, ORCID: 0000-0002-7959-7967

Introduction

Design studies encompass all interdisciplinary research across fields such as architecture, industrial products, and graphics. Being functional and modular, these studies emerge within the framework of human needs. Additionally, they respond to diverse needs and require no additional discipline (Çaydere, 2015, p. 143). At the same time, measuring and analyzing emotional, perceptual, and cognitive human experiences is challenging, as various factors play a role and no single method is sufficient for everyone. Due to these challenges, design disciplines have long incorporated interdisciplinary approaches and methods into their design processes. While methods such as interviews, surveys, and interpretive content analysis, commonly used in research examining human perception and cognition, were quite popular in the past, experimental methods, virtual reality, and biometric measurements have become increasingly popular in recent years (Vartanian et al., 2015; Vecchiato et al., 2011). Design has historically developed as an interdisciplinary field based on creative thinking, problem-solving, and aesthetic decision-making. Although studies on the use of cognitive neuroscience tools in design are increasing, comprehensive assessments that holistically present the field's methodological framework remain limited. A significant portion of existing research focuses on a specific tool or a single design context. In contrast, a general overview that addresses the methods used across the design discipline, prominent research themes, and trends is less common. This makes it difficult to understand the relationship between design and neuroscience in detail and limits systematic progress in the field.

Over the last decade, the number of interdisciplinary neuroscience-based research projects has steadily increased. One of the main reasons for this increase is that technological advancements have enabled different disciplines to produce more scientific, measurable answers to research questions they have long sought to answer. When the goal is to ground social science research in an empirical foundation, neuroscience methods play an important role. These developments have paved the way for the emergence of new concepts that bring together disciplines such as neuromarketing, neuroarchitecture, neuroaesthetics, and neurodesign. Numerous studies are being conducted around these concepts, and increasingly more empirical research is being contributed to the social sciences literature. Today's technologies are also transforming traditional research processes in the social sciences. The inclusion of neuroscience-based approaches in design processes is considered critical, especially in making visual content more meaningful, relevant, and preferable in today's technology-driven world. This research aims to contribute to neurodesign research by providing a current, expanded methodological framework for design. The findings of this scoping study, conducted in accordance with PRISMA-ScR guidelines, aim to strengthen the methodological infrastructure of neuroscience-based research in design and to guide future studies.

An examination of international studies in the literature reveals that they

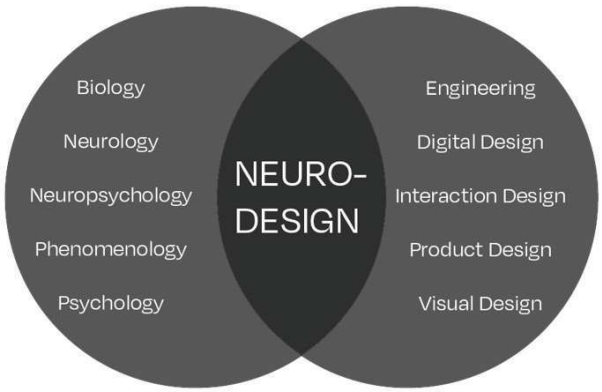
are of great importance in positioning neurodesign as an emerging interdisciplinary field; however, they also exhibit limitations that this study aims to address. For example, the study by Balters et al. (2023) systematically mapped 82 academic studies, identified 9 main themes, and offered a valuable thematic synthesis. Similarly, Ohashi et al. (2022) presented a comprehensive overview of 21 studies focusing on cognitive activities, design activities, and publication trends. However, it was observed that these analyses remained largely descriptive, and interpretations of how these studies shaped the field's methodological foundation were limited. Conversely, Aurnhammer et al. (2020) highlighted interdisciplinary gaps between neuroscience and design but failed to provide a systematic review of existing research.

In contrast, this research aims to advance the field not only by mapping methodological approaches but also by analyzing how neurodesign studies address gaps in design research. Furthermore, the analysis will provide a comprehensive overview of the research examined, including its scope, fields, and key contributions, along with quantitative and tabular summaries. In doing so, it aims to serve as both a methodological reference point and a practical guide for researchers seeking to shape the future trajectory of neurodesign. Furthermore, the Turkish literature has not revealed any academic study focusing on neurodesign or presenting a scoping review related to this field. This research aims to provide researchers in Türkiye with a high-quality resource in this field.

Neurodesign

Neurodesign research is a unique and practical fusion of neuroscience and design research. Like developments in neuroeconomics Glimcher and Rustichini (2004), neurodesign bridges the gap between 'Neuro' - such as neurophysiology, neurology, phenomenology, biology, and psychology - and 'Design' - such as computer science, engineering, product, interaction, and visual design-as illustrated in *Figure 1* (Auernhammer et al., 2023).

Figure 1. Neurodesign: The interdisciplinary intersection of neuroscience and design.



In contrast to design neuroscience, design neurocognition refers to the application of neuroscience tools to investigate questions about thinking/cognition related to design activities. Design neurocognition emerged from previous developments in research on creativity and design cognition (Gero, 2019; von Thienen et al., 2021). Design researchers are examining neurocognitive activities in designs using tools such as EEG, fMRI, and fNIRS (Alexiou et al., 2009; Balters et al., 2023; Goucher-Lambert et al., 2018; Hay et al., 2019; Shealy et al., 2020; Vieira et al., 2020). Design problems encompass components such as the target audience, product, message, and related professional problem-solving processes. The rapid pace of technology consumption, rapid habituation to images, and the resulting insensitivity to them are among the disadvantages of today's technological outputs. As a result, the image generation components for design cells are becoming increasingly complex. Each of these neuroscientifically preserved components facilitates a distinct problem-solving process in design.

Neural dynamics and fuzziness are not merely a state of the human mind; they are inherent in human development and existence, a necessary condition for human learning, growth, and survival. The application of neuroscience in design offers methods and tools that facilitate creative design processes (Hevner et al., 2014). Neurodesign facilitates designers' ability to translate their creative intentions into something users can perceive and respond to. Instead of treating the experience as a 'black box', it examines the cognitive triggers that accompany interaction, focusing on elements that attract attention, require effort, feel rewarding, and deter users. This perspective helps designers and usability experts interpret user behavior with clearer evidence and explain why certain design choices lead to better experiences (Kirkland, 2012).

Design itself is an iterative, goal-oriented activity and relies on the continuous development of complex cognitive skills (Simon, 1977; Ralph & Wand, 2009). From a complementary perspective, cognitive neuroscience leverages methods such as psychophysiology, electrophysiology, and functional neuroimaging to investigate the neurobiological basis of these cognitive processes. In visual design, putting this knowledge into practice can do more than strengthen the product-viewer connection; it can make social issues more visible and, in some contexts, foster positive societal impact. Especially considering that design is an important tool for solving problems, the design criteria used can vary depending on the period in which the design is prepared, its audience, and current trends. Therefore, the scientific approach of neurodesign can support the 'correct' production in design.

Methodology

Scoping reviews, a type of knowledge synthesis, follow a systematic approach to map the evidence on a topic and identify key concepts, sources, theories,

and knowledge gaps. The goal of PRISMA-ScR is to help readers (including researchers, publishers, commissioners, policymakers, healthcare providers, guideline developers, and patients or consumers) develop a better understanding of relevant terminology, core concepts, and key elements to be reported in scoping reviews (Trico A. et al., 2018).

The review methodology developed by Arksey and O'Malley (2005) for conducting a scoping review considers the following five stages:

1. Determining the research question
2. Identifying related studies
3. Study selection
4. Graphing data
5. Compiling, summarizing, and reporting the results.

These five stages are structured within the framework of the research as follows:

Identifying the research question

This study was structured according to the five-stage scoping review methodology developed by Arksey & O'Malley (2005). According to this framework (2005, pp. 6-7), scoping reviews aim to analyze the nature, scope, and content of existing studies on a specific problem or topic; determine the feasibility and potential costs of conducting a systematic review; summarize the findings and scope of research in specific areas; and identify gaps in the literature that could inform future research directions. Accordingly, the first stage of the methodology, identifying the research question, focuses on addressing the following questions:

1. How is the concept of neurodesign defined and addressed in the literature across different disciplines (e.g., neuroscience, design, architecture, user experience, etc.)? What theoretical frameworks or models are used in neurodesign research?
2. In which areas is the current literature on neurodesign primarily focused?
3. What methodologies are predominantly used in these studies (e.g., fMRI, EEG, eye tracking, biometric measurements)?
4. What are the practical applications and impacts of neurodesign in these contexts, and what are the implications of these studies for industry and academia?
5. What are the identified gaps in neurodesign research and suggested directions for future research in this area?

Identifying related studies

Inclusion criteria serve as a guide for researchers to decide which sources to include in a scoping review (Peters et al., 2015, p. 143). In this context, academic publications that included the word 'neurodesign' in their titles, abstracts, and keywords were included in the scoping review. For this research, the *Web of Science* and *Scopus* databases were selected as sources based on their reliability and high academic value. On June 3, 2025, a search was conducted using the keyword 'neurodesign' in the article title, abstract, and keyword filtering.

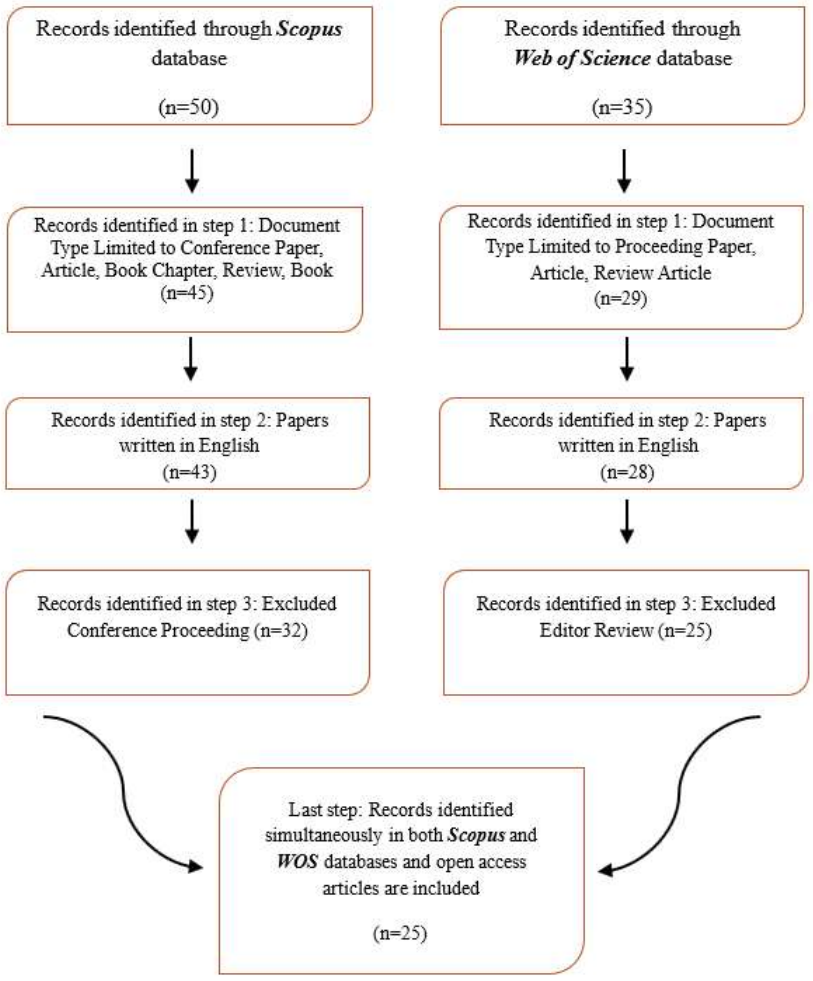
The *Scopus* search yielded 36 research papers from 2009 to 2025, including 12 journal articles, 15 conference proceedings, 2 book chapters, and 3 review articles covering various disciplines. *Scopus'* interdisciplinary inclusion criteria include the following fields: computer science, engineering, social sciences, decision sciences, business, management and accounting, arts and humanities, neuroscience, psychology, multidisciplinary, materials science, economics, econometrics, and finance. Another inclusion criterion was that the studies present findings or research outputs, i.e., they are open access.

The *Web of Science* search yielded four research papers from different disciplines, including two journal articles and two presentations, published between 2012 and 2025. The data were analyzed considering the following criteria: author, number of citations, journal, country, institution, keywords, and abstract content. The years indicated represent the first and last years of neurodesign-related studies published in both databases.

Study selection

Based on the inclusion and exclusion criteria, a total of 32 studies from *Scopus* and 25 from *Web of Science* were eligible for scoping analysis. After applying the curation criteria, 25 studies were included in the final review. The selection process for the study utilized the PRISMA-ScR (PRISMA extension for scoping reviews) flowchart, as recommended by Peters et al. (2015, p. 144), which is illustrated in *Figure 2*.

Figure 2. PRISMA-ScR flow diagram of neurodesign-related articles.



Within the scope of this research, some conference proceedings and book chapters were excluded based on inclusion/exclusion criteria due to their lack of a full academic text and limited methodological detail.

Data graphing

The data from the selected studies are presented in a table format for better visualization. *Table 1* presents the names of researchers and journals, publication years, data collection techniques, themes, research areas, and methodological approaches for studies.

For this review, the use of neurodesign in visual design is classified under the following thematic headings: architectural design, marketing, engineering, and visual communication design.

Compiling, summarizing, and reporting results

This scope-setting review provides a comprehensive overview of the academic literature surrounding the concept of neurodesign. The analysis reveals the interdisciplinary diversity of neurodesign theoretical framework, methodological approaches, and application areas. However, several key gaps in the existing literature have been identified, which points to the need for further interdisciplinary research, particularly regarding the effective integration of neurodesign methods into design education, design practices, and the design industry. The findings of this study are expected to guide both academic and professional circles and lay the groundwork for future research in the field of neurodesign.

Findings

The 25 academic publications included in the scoping analysis were classified according to five categories (author(s) and year, data collection technique, methodological approach, sample, theme, and research area) and tabulated to answer the research questions. Each study was numbered and preceded by the letter A (research) for citation within the article. The methods employed in the research designs of these studies were faithfully cited, in accordance with the authors' own statements. Sev's (2024) study was used as a reference in tabulating and summarizing the studies. *Table 1* lists the articles included in this scoping review.

Table 1. Studies included in the scoping review

Work Number (Research)	Author(s) and Year	Data Collection Technique	Methodological Approach	Sample	Theme and research area
R1	Salingaros (2025a)	AI-based production + content analysis	Quantitative	-	Artificial intelligence-based design (architectural design)
R2	Salingaros (2025b)	Pairwise comparison + content analysis	Quantitative	-	Neurodesign-based facade psychology (architectural design)
R3	Sola et al. (2025)	Content analysis	Quantitative	-	Neurodesign and human-centered design (neuromarketing)
R4	Labrada et al. (2024)	Literature review + observation	Mixed Method	-	User-centered requirements analysis (engineering)

R5	Al-Sharif & Isa (2024)	Systematic literature review + thematic analysis	Quantitative	-	EEG-based neuromarketing studies (neuromarketing)
R6	Liu et al. (2024)	fNIRS + observation	Mixed Method	30 children	Neurodesign-based education (psychology)
R7	Chenais & Görgen (2024)	Literature review	Quantitative	-	Neurodesign-based clinical XR interfaces (health and design)
R8	Göktaş et al. (2024)	Eye tracking	Qualitative	60 participants	Eye tracking-assisted user-product interaction analysis (engineering)
R9	Kwon et al. (2023)	Perspective article	Quantitative	-	NeuroDesign processes (PND) (design)
R10	Hermosilla & Magal-Royo (2022)	Surveys and focus group discussions + Scenario-based user experience analysis	Mixed Method	Potential travelers and experts	Human-centered design requirements (design engineering)
R11	Paoletti & Imbesi (2021)	EEG	Qualitative	A group	Developing user-centered redesign processes based on objective data (design)
R12	Thienen et al. (2021)	Survey and observation	Qualitative	10	Design focused on interaction, motivation and collaboration (neurodesign)
R13	Chowdhury & Chakraborty (2021)	EEG, GSR, eye tracking, survey	Mixed Method	A group of visual communication designers	Digital media and experience design (neurodesign for branding)
R14	Liu et al. (2021)	Literature review	Quantitative	-	User-centered, close design approach (neurodesign)
R15	Auernhammer et al. (2020)	Literature review	Quantitative	-	Human-computer interaction (neurodesign)

R16	Wang et al. (2020)	EEG	Qualitative	30 participants	Neuroaesthetics and automobile design appreciation (engineering)
R17	Zallio et al. (2020)	Case study	Qualitative	People aged 65 and over	User-centered, meaningful and inclusive design (engineering)
R18	Liu et al. (2020)	Literature review	Quantitative	-	User-centered conscious design (neurodesign)
R19	Hou (2019)	ERP (event-related potential) measurements via EEG	Qualitative	31 participants	Neurodesign and semantic cognition (neurodesign)
R20	Cutellic (2019)	EEG-based ERP recordings	Qualitative	Unspecified	Human-machine collaboration (architecture)
R21	Cutellic (2018)	EEG-based ERP recordings	Qualitative	Unspecified	Human-machine interaction in generative design processes (engineering)
R22	Ahram et al. (2016)	Literature review	Quantitative	-	User-centered neurodesign approaches + Human-system interaction (neurodesign)
R23	Cutellic (2014)	Literature review	Quantitative	-	Hybrid design algorithms (architecture)
R24	Cutelic & Lotte (2013)	EEG recordings of neural activity	Qualitative	Unspecified	User-centered optimization, Neurophysiology and Artificial Intelligence (architecture)
R25	Wang et al. (2012)	ERP (event-related potential) measurements via EEG	Qualitative	18 female participants	Neurobiologically based design evaluation (engineering)

According to the results in *Table 1*, the research questions can be answered as follows: How is the concept of neurodesign defined and addressed in the literature across different disciplines (e.g., neuroscience, design, architecture, user experience, etc.)? What theoretical frameworks or models are used in neurodesign research?

Table 2. Distribution by research areas.

Research Area	Research
Architecture	Salingaros, N. A. (2025a; 2025b); Cutellic (2014, 2019); Cutellic & Lotte (2013).
Engineering	Labrada et al. (2024); Göktaş et al. (2024); Hermosilla-Fernandez & Magal-Royo (2022); Wang et al. (2020); Zallio et al, (2020); Cutellic (2018); Wang et al. (2012).
Design-related	Chenais & Görgen (2024); Kwon et al. (2023); Paoletti & Imbesi (2021); Thienen et al. (2021); Chowdhury & Chakraborty (2021); Liu et al. (2021); Auernhammer et al. (2020); Liu et al. (2020); Lu & Hou (2019); Ahram et al. (2016).
Neuromarketing	Sola et al. (2025); Alsharif & Isa (2024).
Psychology	Liu et al. (2024).

The data in *Table 2* show that the most researched discipline within the neurodesign framework is visual design (10 studies). This is followed by engineering (7 studies) and architecture (5 studies). There are two studies directly related to neuromarketing and one to psychology. Among the studies mentioned in the table, the first study related to the design, Ahram et al. (2016), is a literature review. This research examines the concept of neurodesign within the context of neuroscience and user experiences. The research highlights the uncertainty (fuzziness) and dynamism inherent in the relationship between product design, user perceptual complexity, and human factors, arguing that this uncertainty is a natural part of human development and interaction with the environment. Consequently, it suggests that designers and engineers should design systems that take this inherent nature of user cognitive processes into account. It also indicates that neuroscience-based approaches and emotional design research offer an important avenue for better understanding and improving user-product interactions in the future. In Hou's (2019) study with 31 participants, ERP and EEG were used to conduct comprehensive neurocognitive analyses of meaningful congruence and incongruence in sign designs from a neuroscience perspective. The study's results suggest that neural hotspots can be established for meaningful experiments in sign design. Because the signs used encompass features such as cities and other life spans, they supplement a new sign design system. Because abandoning traditional sign designs is time-consuming, these robust and durable designs are presented. These design proposals offer a measurement method that will remain relevant in the future. Liu et al.'s (2020) study is also a literature re-

view, and it emphasizes that neurodesign is a new interdisciplinary field that combines psychology, neuroscience, computer science, and design. It is also stated that this new field of study aims to facilitate the scientific analysis and interpretation of this humanities field by providing cognitive neuroscience data that supports design science. This research argues that a neurodesign collaborative approach to design processes will strengthen decision-making and problem-solving. Auernhammer et al.'s (2020) literature review indicates that neuroscience tools (e.g., fNIRS, fMRI, EEG) can be used in neurodesign research to understand collaboration and creativity in design teams better. The critical point in this perspective is the focus on cognitive interactions at the team level rather than the individual's solitary thought processes. Examining intra-team interactions is considered a crucial step in enhancing creativity, empathy, decision-making, and teamwork capabilities. On the other hand, this research initiative is not limited to producing only an academic output. It also aims to develop new measurement methods, create new research agendas, and strengthen an interdisciplinary community that can guide designers towards more creative and effective solutions.

Liu et al. (2021) state that UX education cannot be limited to usability and technical skills alone and requires an integrated approach that brings together disciplines such as psychology, design, engineering, and business. In this context, the study examined and evaluated emerging needs in UX education by focusing on the UX program (BNUX) at Peking Normal University. The research concluded that the program lacks a long-term roadmap for the AR/VR field, emphasizing the need to develop a more holistic and integrated framework with a master plan. Generally, the neurodesign literature focuses on topics such as design, user experience (UX), human-computer interaction (HCI), and the measurement of emotion and cognitive processes.

In which domains are the current body of neurodesign-related literature concentrated? What methodologies are predominantly used in these studies (e.g., fMRI, EEG, eye tracking, biometric measurements)?

Table 3. Distribution according to research methodologies.

Research Methodologies	**Measurement Technique**
Quantitative	Salingaros, N., A. (2025a; 2025b); Sola et al. (2025); Alsharif et al. (2024); Chenais & Görgen (2024); Kwon et al. (2023); Liu et al. (2021); Auernhammer et al. (2020); Liu et al. (2020); Ahram et al. (2016); Cutellic (2014).
Qualitative	Liu et al. (2024), *fNIRS*; Göktaş et al. (2024), *eye tracking;* Thienen et al. (2021), *research and observation*; Wang et al. (2020), EEG; Zallio et al. (2020), *case study*; Lu & Hou (2019), *EEG*; Cutellic (2018; 2019), *EEG*; Cutelic, & Lotte (2013), *EEG*; Wang et al. (2012), *EEG.*

Mixed method	Labrada & Fonseca (2024), *literature review + observation;* Liu et al. (2024), *fNIRS + observation;* Hermosilla-Fernandez & Magal-Royo (2022), *surveys and focus group discussions;* Chowdhury & Chakraborty, P. (2021), *EEG, GSR, eye tracking, surveys.*

Table 3 presents a review of 25 articles on the concept of neurodesign in the *Scopus* and *WOS* databases, revealing that 11 studies are quantitative, 10 are qualitative, and 4 are mixed methods. This table also shows that the majority of methodologies used in neurodesign fall within the scope of qualitative research methodology, with fNIRS, GSR, EEG, and eye tracking being the most frequently used. There are also mixed-method studies that combine cognitive neuroscience instruments with traditional research methods such as surveys. These mixed-method studies combine objective data and subjective user feedback to yield holistic results. According to the data presented in the table, most studies using cognitive neuroscience tools employ EEG measurement techniques. The main reason for this is the high accessibility of EEG and its ability to directly reflect user experience by measuring real-time brain activity. Other cognitive neuroscience tools used (fNIRS, EEG, GSR, and eye tracking) each allow researchers to understand different cognitive and emotional processes of users. Therefore, the aim of choosing a qualitative approach is not only to observe user/viewer behaviour but also to uncover the neurobiological mechanisms underlying it. Again, according to this table, the qualitative approach is the most preferred approach in the neurodesign literature. Researchers can primarily use this method to obtain and interpret scientific outputs by focusing on a profound understanding of users' cognitive and emotional responses to designs.

What are the practical applications and impacts of neurodesign in these contexts, and what are the implications of these studies for industry and academia?

Based on the reviewed studies indexed by *Web of Science* (2012–2025) and *Scopus* (2009–2025), neurodesign has been applied in a variety of practical areas:

Visual communication and media design

When the research is examined within the scope analysis framework, it is evident that visual communication studies are increasingly using EEG, eye-tracking, and related biometric measurements as evaluation tools, particularly to capture where users are looking, how strongly they respond, and when the interaction becomes mentally challenging. In practice, this approach extends beyond design evaluation and can be applied in areas such as advertising, brand building, packaging, and digital media. This is because many communication options operate at a level that users cannot fully express verbally, so measuring attention patterns and implicit responses can guide more effec-

tive message design. These methods can also be used to propose new evaluation criteria for problem-solving in public visual communication, including public information materials and public service announcements.

Architecture

When examining the research included in this study, it is observed that in research focusing on architecture and spatial design, cognitive neuroscience tools are used to analyse how features such as spatial arrangement, light, and material qualities shape user responses (both in terms of emotion and underlying neural activity). This field of study examines the built environment as something constantly interacting with perception, comfort, and decision-making, rather than treating spaces as static objects. Practical outcomes often aim to improve wayfinding, perceived safety, and overall spatial experience. For architects, such evidence can help transform complex lived experience questions into testable design parameters, which is becoming increasingly crucial as shared living spaces become denser and more interconnected. Utilizing cognitive neuroscience tools in this field can provide a significant advantage for architectural designers. As population growth leads to denser, more interconnected shared living spaces, it becomes possible to evaluate how users perceive and experience these spaces with more concrete data. Thus, 'livability' criteria can be based not only on assumptions but also on findings that support user experience. Discussing the applicability of rapidly changing architectural trends to neurodesign criteria can also help generate new evaluation criteria for the field. This approach has the potential to improve the quality of architectural design by more directly incorporating user experience into design decisions.

User experience (UX) and human-computer Interaction (HCI)

The research examined in this article, focusing on user experience (UX) and human-computer interaction (HCI), utilizes neurodesign-focused methods to observe cognitive and emotional states during interaction, aiming to improve interface decisions that impact usability and comprehension. By combining behavioral data with metrics related to attention and workload, researchers can better identify moments when users hesitate, lose interest, or become overloaded. This supports usability testing, informs adaptive interface concepts, and contributes to systems that respond more appropriately to users' emotional cues. In this sense, neuroscientific experiments, rather than replacing UX practice, can serve as an additional layer of evidence to help designers justify their interface choices and improve user-centric outcomes. Furthermore, in the evolving world of technology, new criteria can be proposed for creating interface designs tailored to the target audience. This allows designers to optimize functionality by creating sample groups for the users they target.

Marketing and consumer research

In marketing-focused research within the scope of this study, neuroscience applications such as fMRI, EEG, and eye tracking are widely used to analyze consumer decision-making processes, brand perception, and purchasing behavior. This type of information is increasingly adopted by industries seeking to design engaging and user-centric products and campaigns. Neuroscience and marketing have long applied an interdisciplinary approach to neuromarketing. The relationship between marketing, consumer research, and neurodesign, the subject of this study, is closely tied to the visual content design processes in these studies. In other words, they not only market a brand or product to consumers but also manage processes to measure how and for how long campaign visuals influence them.

The relationship of neurodesign with industry provides empirical data beyond self-reports, enabling companies to improve products, services, and environments based on real neural and physiological responses. Industries (product, gaming, retail, architecture) and public institutions (government agencies, hospitals, foundations) that adopt neurodesign methodologies are generating more effective and differentiated designs by gaining insights into subconscious user benefits. This clearly distinguishes neurodesign from neuromarketing. The neurodesign approach is clearly user-focused. The relationship of neurodesign with academia is likely to foster collaboration across neuroscience, psychology, design, and engineering. Research is contributing to the creation of new conceptual frameworks that bridge the gap between cognitive neuroscience and design theory. The adoption of neuroimaging and biometric methods is also helping to expand the methodological toolset of design research. Neurodesign findings play an important role in shaping future design professionals by encouraging the inclusion of neuroscience-based approaches in design curricula.

Neurodesign is practically applied in visual communication, UX/HCI, architecture, and consumer research, with significant impacts on both industrial innovation (user-centered, data-driven design practices) and academic advancement (interdisciplinary theory, methods, and education).

What are the identified gaps in neurodesign research, and what are the suggested directions for future research in this area?

An examination of the 25 studies included in the study revealed several gaps in neurodesign research and offered suggestions for future research. First, the concept of 'neurodesign' appears to have varying meanings across disciplines. Standard definitions for common concepts such as attention, emotion, and cognitive load, and the ability to formulate clear hypotheses between theory and method, are limited. This can undermine the comparability of findings and the generation of knowledge across studies. Therefore, increasing the number of theory-based studies and generating original, clear

hypotheses would contribute to the field.

The studies reviewed have not consistently demonstrated the compatibility of behavioral and neural metrics. Therefore, design recommendations based solely on correlated signals remain limited. Integrating multimodality (EEG, eye tracking, and GSR) and causality-focused protocols into a holistic study could help address this limitation.

Studies are limited in their sample selection, which opens new avenues for research by exploring the impact of factors such as cross-cultural approaches and generational differences on design processes. Design outcomes have varying effects on different users. Therefore, future studies focusing on cross-cultural, multicentered, and neurodiversity aspects will allow this field to develop.

Discussion

Upon reviewing the 25 studies included in this scope review, it becomes clear that 'neurodesign' is considered an interdisciplinary umbrella concept. It is applied in various ways across different contexts. However, in most cases, the methods used complement one another. In the architecture-focused literature, Cutellic (2018) and Salingaros (2025a) observe that neurophysiological signals - especially EEG - are more frequently incorporated into the design process and integrated as feedback into production processes such as generative design or human-computer collaboration. In contrast, in engineering and industrial design studies, Wang et al. (2020) and Göktaş et al. (2024) use neurophysiological measurements primarily as outcome-oriented evaluation tools to assess the design output, validate the final product, analyze usability, or infer user needs. In neuromarketing studies, Al-Sharif & Isa (2024) emphasize variables related to brand perception rather than technical performance; they discuss perception and preference processes by measuring consumers' emotional and implicit (unconscious) responses.

When studies are coded by their primary analytical focus to synthesize these patterns, a recurring tripartite structure emerges. Architectural studies often prioritize process-level integration, engineering and industrial design studies prioritize performance and validation, and marketing studies prioritize perception and affect. However, the design research included in this study does not directly fit into a single axis; rather, it tends to address the dimensions of meaning production, process, and interaction together. This finding suggests that neurodesign is positioned not only as a set of measurement tools but also as a framework/interpretation approach for design research. Methodologically, neurodesign research has significant advantages and limitations. Biometric and neurophysiological measurements can provide real-time data that is not entirely dependent on self-report; however, these methods require specialized equipment and expertise, and laboratory condi-

tions can limit participants' natural experience, reducing ecological validity. Furthermore, using physiological data alone can lead to interpretability problems, especially when applied to higher-level constructs such as 'meaning', 'aesthetic judgment', or 'quality of interaction'. Therefore, mixed methods designs are increasingly being adopted in studies.

When quantitative measurements are combined with qualitative data (e.g., interviews, expert evaluations), it is possible to reach more robust conclusions through the mutual validation of findings across different sources. Liu et al. (2024) provide a good example of this type of triangulation approach. However, the most significant disadvantage of mixed methods is that combining different data types within the same analytical framework is both analytically challenging and increases measurement costs. Another point revealed by this review is that neurodesign applications progress iteratively at two levels, depending on the interdisciplinary context. In outcome-oriented studies, neurophysiological data are primarily used to evaluate and validate the design. In contrast, process-oriented approaches incorporate this data into the production and decision-making steps, making it an active part of the design cycle. This distinction suggests that neurodesign has evolved from being merely a measurement technique into a methodological identity within the discipline in which it is addressed. Furthermore, it is observed that design-oriented studies have a more distinctive character than applications in architecture and engineering. It is predicted that future global trends will further strengthen the contribution of neurodesign, particularly to the field of visual design.

Conclusion

This scope analysis classifies 25 academic studies on the concept of neurodesign by discipline, methodological approach, and data collection techniques, providing a general overview of the field. The findings show that neurodesign research is significantly concentrated in design-oriented topics. Most studies were conducted in the context of user experience (UX), human-computer interaction (HCI), and visual communication, followed by studies in architecture and engineering, psychology, and neuromarketing. This distribution suggests that neurodesign is positioned not only as an approach that "measures the designer," but also as a research orientation that supports decision-making in areas that interact with users. Among neuroscientific tools, EEG and eye-tracking methods stand out. This preference can be attributed to the relative accessibility of these methods and their suitability for real-time monitoring of processes, such as attention/perception, that accompany the design process. A smaller number of studies preferred fNIRS, GSR, or multimodal designs combining multiple measurements. However, the literature still shows a significant reliance on single-measurement-based designs (especially EEG). When examining methodological trends, it is understood that qualitative and exploratory studies currently dominate the literature, but the mixed-methods

approach is increasingly being adopted.

Mixed-methods studies combine neurophysiological findings with data such as interviews, surveys, and behavioral observations, making the aspects of design decisions that extend beyond the output to the process and context more legible. From an application perspective, neurodesign is used in visual communication and media design to evaluate variables such as attention and cognitive load, and in architecture and UX/HCI contexts to support the development of user-centered, more responsive solutions. However, the survey findings point to some recurring problems hindering the maturation of the field: lack of standardization in the definition and scope of neurodesign in the literature, the weakness of the theoretical framework in most studies, excessive reliance on single-measurement designs, and the limited treatment of cultural differences and neurodiversity variables are among the main problems. This table shows that, while neurodesign has promising potential, its fragmented, exploratory accumulation of knowledge requires a stronger theoretical and methodological framework.

Finally, the findings also indicate that the place of neuroscience-based approaches in design education and vocational training needs to be strengthened. While technology in design education often transforms visual production processes, the controlled and ethical use of cognitive neuroscience tools can make the communication produced by designs more measurable to the target audience. In general, neurodesign appears to be a developing research area that, when supported by appropriate theoretical frameworks, multiple measurement approaches, and interdisciplinary/intercultural studies, can make more substantial contributions to both academic theory production and evidence-based design practice.

References

Ahram, T., Falcão, C., Barros, R. Q., Soares, M. M., & Karwowski, W. (2016). Neurodesign: Applications of neuroscience in design and human–system interactions. In M. M. Soares & F. Rebelo (Eds.), *Ergonomics in design: Methods & techniques*. CRC Press. https://doi.org/10.1201/9781315367668

Alexiou, K., Zamenopoulos, T., Johnson, J. H., & Gilbert, S. J. (2009). Exploring the neurological basis of design cognition using brain imaging: Some preliminary results. *Design Studies, 30*(6), 623–647. https://doi.org/10.1016/j.destud.2009.05.002

Alsharif, A. H., & Isa, S. M. (2024). Electroencephalography studies on marketing stimuli: A literature review and future research agenda. *International Journal of Consumer Studies, 49*(1). https://doi.org/10.1111/ijcs.70015

Auernhammer, J., Sonalkar, N., & Saggar, M. (2021). NeuroDesign: From neuroscience research to design thinking practice. In C. Meinel & L. Leifer (Eds.), *Design thinking research: Understanding innovation* (pp. 347-355). Springer. https://doi.

org/10.1007/978-3-030-62037-0_16

Auernhammer, J., Liu, W., Ohashi, T., Leifer, L., Byler, E., & Pan, W. (2021). NeuroDesign: Embracing neuroscience instruments to investigate human collaboration in design. In T. Ahram, R. Taiar, K. Langlois, & A. Choplin (Eds.), *Human interaction, emerging technologies and future applications III* (Advances in Intelligent Systems and Computing, Vol. 1253, pp. 284-289). Springer. https://doi.org/10.1007/978-3-030-55307-4_43

Auernhammer, J., Bruno, J., Booras, A., McIntyre, C., Hasegan, D., & Saggar, M. (2023). NeuroDesign: Greater than the sum of its parts. In C. Meinel & L. Leifer (Eds.), *Design thinking research: Understanding innovation* (pp. 197–211). Springer. https://doi.org/10.1007/978-3-030-55307-4_43

Balters, S., Weinstein, T., Mayseless, N., Auernhammer, J., Hawthorne, G., Steinert, M., Meinel, C., Leifer, L. J., & Reiss, A. L. (2023). Design science and neuroscience: A systematic review of the emergent field of design neurocognition. *Design Studies, 84*, 101148. https://doi.org/10.1016/j.destud.2022.101148

Chowdhury, A., & Chakraborty, P. (2021). Memes that evoke emotions: A neurodesign strategy for brand communication and experience. In *Design for Tomorrow* (Vol. 1, pp. 147–156). Springer. https://doi.org/10.1007/978-981-16-0041-8_13

Çaydere, O. (2015). *Faculty and student opinions on graphic design programs* (Unpublished doctoral thesis). Gazi University Institute of Educational Sciences.

Chenais, N., & Görgen, A. (2024). Immersive interfaces for clinical applications: Current status and future perspective. *Frontiers in Neurorobotics, 18*. https://doi.org/10.3389/fnbot.2024.1362444

Cutellic, P., & Lotte, F. (2013). *Augmented iterations: Integrating neural activity in evolutionary computation for design*. HAL Open Science.

Cutellic, P. (2014). Le cube d'après: Integrated cognition for iterative and generative designs. In *Proceedings of the ACADIA Conference*. https://doi.org/10.13140/RG.2.1.5186.5444

———— (2018). An event-based generative design software implementing fast discriminative cognitive responses from visual ERP BCI. In *Human–computer interaction in design* (Vol. 2, pp. 131-138). https://doi.org/10.52842/conf.ecaade.2018.2.131

———— (2019). Towards encoding shape features with visual event-related potential–based brain–computer interfaces for generative design. *International Journal of Architectural Computing, 17*(1). https://doi.org/10.1177/1478077119832465

Glimcher, P. W., & Rustichini, A. (2004). Neuroeconomics: The consilience of brain and decision. *Science, 306*(5695), 447–452. https://doi.org/10.1126/science.1102566

Goucher-Lambert, K., Moss, J., & Cagan, J. (2018). Inspired internal search: Using neuroimaging to understand design ideation and concept generation with in-

spirational stimuli. In *Proceedings of the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. https://doi.org/10.1115/DETC2018-85690

Göktaş, O., Ergin, E., Çetin, G., Özkoç, H. H., Fırat, A., & Gazel, G. G. (2024). Investigation of user–product interaction by determining the focal points of visual interest in different types of kitchen furniture: An eye-tracking study. *Displays, 83*, 102745. https://doi.org/10.1016/j.displa.2024.102745

Hay, L., Duffy, A. H. B., Gilbert, S. J., Lyall, L., Campbell, G., Coyle, D., & Grealy, M. A. (2019). The neural correlates of ideation in product design engineering practitioners. *Design Science,* 5, e29. https://doi.org/10.1017/dsj.2019.27

Hermosilla, C., & Magal-Royo, T. (2022). User experience requirements for hyperloop passengers' cabin. *DYNA, 97*(4). https://doi.org/10.6036/10480

Hevner, A. R., Davis, C., Collins, R. W., & Gill, T. G. (2014). A neurodesign model for IS research. *Informing Science: The International Journal of an Emerging Transdiscipline, 17*, 103–132.

Kirkland, L. (2012). *Using neuroscience to inform your UX strategy and design*. Retrieved May 14, 2025 from https://www.uxmatters.com/mt/archives/2012/07/using-neuroscience-to-inform-your-ux-strategy-and-design.php

Kwon, J., Linihan, S., Iedema, A., Schmidt, A., Luo, C., & Marrufo, K. (2023). How interior design responds to neurodiversity: Implementing wearable technologies in neurodesign processes. *Frontiers in Built Environment, 9*. https://doi.org/10.3389/fbuil.2023.1211519

Labrada, S. M., Fonseca, E. M., & Marquez-Barja, J. M. (2024). Requirement system for the interface design of applications for children with neurodevelopmental disorders. In *Proceedings of the IEEE Global Engineering Education Conference (EDUCON)*. https://doi.org/10.1109/EDUCON60312.2024.10578799

Liu, Q., Huang, R., Zhu, R., & Chen, Y. (2024). Exploring neurodesign in cultivating empathy and creativity in primary education in China. https://doi.org/10.1145/3675094.3677596

Liu, W., Jin, Y., Li, B., Lyu, Z., Pan, W., Wang, N., & Zhao, X. (2020). NeuroDesign: Making decisions and solving problems through understanding of the human brain. In A. Marcus & E. Rosenzweig (Eds.), *Human–computer interaction* (LNCS Vol. 12200). Springer. https://doi.org/10.1007/978-3-030-49713-2_14

Liu, W., Lee, K. P., Gray, C. M., Toombs, A. L., Chen, K. H., & Leifer, L. (2021). Transdisciplinary teaching and learning in UX design: A program review and AR case studies. *Applied Sciences,* 11, 10648. https://doi.org/10.3390/app112210648

Lu, G., & Hou, G. (2020). Effects of semantic congruence on sign identification: An ERP study. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 62*(5). https://doi.org/10.1177/0018720819854880

Ohashi, T., Auernhammer, J., Liu, W., Pan, W., & Leifer, L. (2022). NeuroDesignScience: Systematic literature review of current research on design using neu-

roscience techniques. In J. S. Gero (Ed.), *Design computing and cognition '20* (pp. 575–592). Springer. https://doi.org/10.1007/978-3-030-90625-2_34

Paoletti, A., & Imbesi, L. (2021). A neurodesign case study: Measuring the emotional index for redesign. *Design Principles and Practices: An International Journal, 15*(1), 33–44. https://doi.org/10.18848/1833-1874/CGP/v15i01/33-44

Ralph, P., & Wand, Y. (2009). A proposal for a formal definition of the design concept. In K. Lyytinen, P. Loucopoulos, J. Mylopoulos, & B. Robinson (Eds.), *Design requirements engineering: A ten-year perspective* (Lecture Notes in Business Information Processing, Vol. 14, pp. 103–136). Springer. https://doi.org/10.1007/978-3-540-92966-6_6

Salingaros, N. A. (2025a). Environments that boost creativity: AI-generated living geometry. *Multimodal Technologies and Interaction, 9*(38). https://doi.org/10.3390/mti9050038

———— (2025b). Façade psychology is hardwired: AI selects windows supporting health. *Buildings, 15*(1645). https://doi.org/10.3390/buildings15101645

Shealy, T., & Gero, J. S. (2019). The neurocognition of three engineering concept generation techniques. *Proceedings of the Design Society: International Conference on Engineering Design, 1*(1), 1833–1842. https://doi.org/10.1017/dsi.2019.189

Simon, H. A. (1977). *The new science of management decision*. MIT Press.

Sola, H. M., Qureshi, F. H., & Khawaja, S. (2025). Human-centered design meets AI-driven algorithms: Comparative analysis of political campaign branding in the Harris–Trump presidential campaigns. *Informatics, 12*(30). https://doi.org/10.3390/informatics12010030

Thienen, J. V., Borchart, K. P., Jaschek, C., Krebs, E., Hildebrand, J., Ratz, H., & Meinel, C. (2021). Leveraging video games to improve IT solutions for remote work. In *Proceedings of the IEEE Conference on Games*. IEEE. https://doi.org/10.1109/CoG52621.2021.9618986

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., … Moher, D. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine, 169*(7), 467–473. https://doi.org/10.7326/M18-0850

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Gonzalez-Mora, J. L., Leder, H., Modroño, C., Nadal, M., Rostrup, N., & Skov, M. (2015). Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach–avoidance decisions. *Journal of Environmental Psychology,* 41, 10–18. https://doi.org/10.1016/j.jenvp.2014.11.006

Vecchiato, G., Astolfi, L., Fallani, F. D. V., Toppi, J., Aloise, F., Bez, F., Wei, D., Kong, W., Dai, J., Cincotti, F., Mattia, D., Babiloni, F., & Babiloni, C. (2011). On the use of EEG or MEG brain imaging tools in neuromarketing research. *Computational Intelli-*

gence and Neuroscience, 2011, 643489. https://doi.org/10.1155/2011/643489

Vieira, S., Gero, J. S., Delmoral, J., Gattol, V., Fernandes, C., Parente, M., & Fernandes, A. A. (2020). The neurophysiological activations of mechanical engineers and industrial designers while designing and problem-solving. *Design Science, 6*, e26. https://doi.org/10.1017/dsj.2020.26

Zallio, M., Berry, D., & Leifer, L. J. (2020). Meaningful age-friendly design: Case studies on enabling assistive technology. In T. Ahram & C. Falcao (Eds.), *Advances in usability and user experience* (Advances in Intelligent Systems and Computing, Vol. 972, pp. 779–790). Springer. https://doi.org/10.1007/978-3-030-19135-1_76

Wang, R. W. Y., Ke, T. M., Chuang, S. W., & Liu, I. N. (2020). Sex differences in high-level appreciation of automobile design–evoked gamma broadband synchronisation. *Scientific Reports,* 10, 66515. https://doi.org/10.1038/s41598-020-66515-7

Wang, X., Huang, Y., Ma, Q., & Li, N. (2012). Event-related potential P2 correlates of implicit aesthetic experience. *NeuroReport, 23*(14), 862–866. https://doi.org/10.1097/WNR.0b013e3283587161

Ethics committee approval: There is no need for ethics committee approval.
Conflict of interest: There are no conflicts of interest to declare.
Financial support: No funding was received for this study.
Author contribution rate: S. Kırteke (50%), E. Toy (50%).

Etik Kurul Onayı: Etik kurul onayına ihtiyaç bulunmamaktadır.
Çıkar çatışması: Çıkar çatışması bulunmamaktadır.
Finansal destek: Finansal destek bulunmamaktadır.
Yazar Katkı Oranı: S. Kırteke (%50), E. Toy (%50).