

Intelligent systems and consumer neuroscience in the age of computational advertising

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Abstract. *The main goal of this article is to provide an overview of the use and characteristics of intelligent systems and neuroscience tools applicable in the field of contemporary advertising. The newly emerging field of computational advertising is undergoing dynamic development, and this concept is now placed in the context of advanced intelligent systems, artificial intelligence, and virtual reality. According to the specified parameters, a systematic literature search of scientific publications was carried out and subsequently evaluated. The research questions are focused on the identification of intelligent systems and current consumer neuroscience tools finding application in the current trend of computational advertising. It follows from the processed systematic literature review that there are currently a number of intelligent systems and also a number of tools in the field of consumer neuroscience that can find application within the broader concept of computational advertising. These more or less intelligent systems and neuroscientific tools are already affecting all phases of the advertising life cycle. At the same time, a number of ethical issues associated with the use of both these technologies and tools have been found, which still need to be explored. The article attempts to fill the gap in the lack of literature dealing with this issue. Last but not least, the article contains a critical view of these new technological possibilities and also describes a number of new ethical challenges arising in this area.*

Keywords: intelligent systems, consumer neuroscience, computational advertising, artificial intelligence, ethical concerns.

Please cite the article as follows: Zámečník, R., (2024), "Intelligent systems and consumer neuroscience in the age of computational advertising", *Management & Marketing*, Vol. 19, No. 3, pp. 441-470, DOI: 10.2478/mmcks-2024-0020.

Introduction

Today's era offers wide possibilities in the field of application of information technology, intelligent systems, and also applications of artificial intelligence, which create a dynamic and turbulent environment for advertising and all related technologies. The area of computational advertising is taking shape. This area originally emerged as a sub-discipline at the intersection of information retrieval, statistical modelling, machine learning and text analysis, as discussed in Kushal & Vasudeva (2014). Also, Dave and Varma (2014) understand computational advertising mainly in the context of online advertising or web advertising, while they consider its purpose to be the search for the most relevant ads in relation to the context on the web. In this spirit, a number of technically and mathematically oriented works

are published (Broder, 2011; Jahanbakhsh, 2020; Liu, 2007; Stevens, 2021; Valitutti et al., 2008). The next level was a more general understanding of the concept of computational advertising presented by Yang et al. (2017). They understand computational advertising as a wider spectrum of computational systems, partial decision-making activities, methods and technologies in advertising and promotion. The development gradually reached the opinion of Huh and Malthouse (2020), who perceive this new phenomenon as a significant paradigm shift rather than as a mere new type of advertising subfield or the application of new technological possibilities. The understanding of computational advertising was placed in the context of advanced intelligent systems, artificial intelligence, virtual reality, and augmented reality very recently by Chu et al. (2024). These new technologies not only support the creation, testing and targeting of advertising, but also its commercial deployment, as well as the evaluation of its effectiveness. These innovative digital technologies, including specific applications of artificial intelligence, are already widely available and also enable the analysis and understanding of consumer behaviour and decision-making in both natural and digital environments. Helberg et al. (2020) also states that artificial intelligence and machine learning technology are now starting to be introduced into computational advertising. Today, these technologies represent more or less intelligent systems that make it possible to create innovative and effective advertising campaigns. Many studies have already focused on the benefits of the partial use of intelligent systems in various fields. Helberg et al. (2020) consider data collection and their analysis to be part of the concept of computational advertising. In this sense, applications of advanced computer and intelligent systems, including artificial intelligence, are also today's tools of consumer neuroscience or neuromarketing, which can also be considered a part of computational advertising. There is also a lot of literature on the topic of using neuroscience tools. However, there is a lack of literature that comprehensively examines these intelligent and neuroscientific tools, as well as how they can be effectively linked for use in modern advertising. There is a lack of literature to provide such guidance for both researchers and practitioners in the field. This systematic literature review therefore tries to fill this gap with its content by showing an overview of the literature to analyse the problems associated with intelligent technologies and consumer neuroscience tools potentially usable in computational advertising,, their adoption in advertising and the introduction of these technologies into real use. The main aim and purpose of this article is to provide a targeted specialised overview of the uses and properties of such intelligent systems and intelligent neuroscience tools. This article examines two main research questions:

RQ1: Which intelligent systems find application in the current trend of computational advertising?

RQ2: Which of the current tools of consumer neuroscience find application in the current trend of computational advertising?

The answers to these questions are addressed in this paper and are a contribution to a more detailed interdisciplinary description of the computational advertising ecosystem, as called for by Huh and Malthouse (2020), and are also a contribution to a more detailed description of the concept of advertising measurement applicable to computational advertising, as stated by Yun et al. (2020).

In order to achieve this goal, a systematic literature review was conducted as described in the Research methodology section. In the section Intelligent systems in

contemporary advertising, there is an overview of today's available applications of intelligent systems in contemporary advertising, an analysis of their use, as well as a proposal for their classification. In the Advertising and consumer neuroscience section, there is an overview of consumer neuroscience techniques or of neuromarketing currently applicable in advertising, including their characteristics and use. Various specific applications of consumer neuroscience tools in advertising are studied here. In the Discussion section, we discuss the various characteristics and uses of various intelligent systems and consumer neuroscience tools in advertising. Finally, in the Conclusion section, we present the conclusions of our study, including an analysis of some ethical concerns that some authors state. These ethical concerns stem both from the abundant use of personal data by intelligent systems, artificial intelligence applications, and intelligent consumer neuroscience tools, and also stem from completely new, hitherto unknown abilities, possibilities, and skills of these innovative technologies. This section also describes the limitations of this systematic literature review.

Literature review

Today, we have at our disposal not only a large amount of data and information, but also advanced technologies. The external environment has also changed significantly due to digitisation. Dahlen and Rosengren (2016) state their broader new definition of advertising in these new current conditions literally as brand-initiated communication intent on impacting people. The current trend and the collective term computational advertising includes, according to Yang et al. (2017), the use and application of a whole spectrum of different advertising methods and applications of a number of different technologies or computer applications. This term also includes promotional behavioural analytics and decision-making process analysis. According to them, this concept has an interdisciplinary character and so far mainly includes the fields of computer science, artificial intelligence, advertising, marketing, linguistics, statistics, economics, psychology, and sociology. Chu et al. (2024) also mentions computational advertising in connection with intelligent systems and artificial intelligence. According to Huh and Malthouse (2020), computational advertising lies at the intersection of advertising, marketing, computer science, information technology, and management information systems. Helberg et al. (2020) broadly discuss the concept of computational advertising including the entire new advertising ecosystem, while trying to identify its key actors and the interactions between them. They talk about the new advertising industry, which includes new ad content creators, new media platforms, and media content providers and, last but not least, also new advertising technology infrastructure providers that facilitate data collection, analysis, and data-based ad delivery. Helberg et al. (2020) also highlight the current and future role of artificial intelligence in this new type of advertising industry. Yun et al. (2020) consider computational advertising to be a great opportunity for measuring the short-term and long-term effectiveness of advertising. Yang et al. (2017) literally states that by computational advertising we mean capabilities to employ mathematical, IT, physical, and economic approaches in order to be able to expressively represent a rich set of advertising objects and environments with the aim to provide efficient, optimal solutions for advertising, decision making, and market design. Huh and Malthouse (2020) define computational advertising literally as a broad, data-driven advertising approach relying on or facilitated by enhanced computing capabilities, mathematical models/algorithms, and the technology infrastructure to create and deliver messages and monitor/surveil an individual's behaviours. In computational advertising, they

include the entire advertising process, from analysis of the market situation, segmentation, and targeting, through the creation of advertising messages and placement in the media to the evaluation of campaign results. Computational advertising includes all advertising and related activities in both online and offline environments, across different types of media, and in different market contexts, as discussed by Huh & Malthouse (2020). Yang et al. (2017) include new forms of advertising in computational advertising, especially contextual advertising, sponsored search, real-time bidding advertising, display advertising, viral advertising, social advertising, and textual advertising, mobile advertising. Some authors (Huh and Malthouse, 2020; Yun et al., 2020; Helberger et al., 2020; Van Noort et al., 2020) widely discuss the issue of how to implement computational approaches to advertising research. One of the ways can be the use of digital and digitalizable methods of consumer neuroscience. Huh & Malthouse (2020) state that the key characteristics of computational advertising according to them are that advertising is individually addressable, data driven, interactive, continuous, and measurable. They also state that the field of computational advertising is still in its infancy and there are still many unexplored research paths, both conceptual and methodological, despite the fact that the concept of computational advertising is widely accepted and rapidly expanded. Huh & Malthouse (2020) also call for creating a clear and comprehensive picture of the computational advertising ecosystem and exploring new areas.

Research methodology

In this article, the systematic literature review methodology presented in Okoli (2015) and also the methodology presented by Goug et al. (2017) are used to implement and evaluate a systematic literature review and create an overview of the use, characteristics, and current state of knowledge on the application of consumer neuroscience and intelligent systems in the field of advertising. The planning of the work on the systematic review took place according to the methodology of Okoli (2015) and also the methodology reported by Goug et al. (2017) and Webster and Watson (2002). The work on the systematic literature review was carried out according to the methodology of Okoli (2015) as shown in Figure 1.

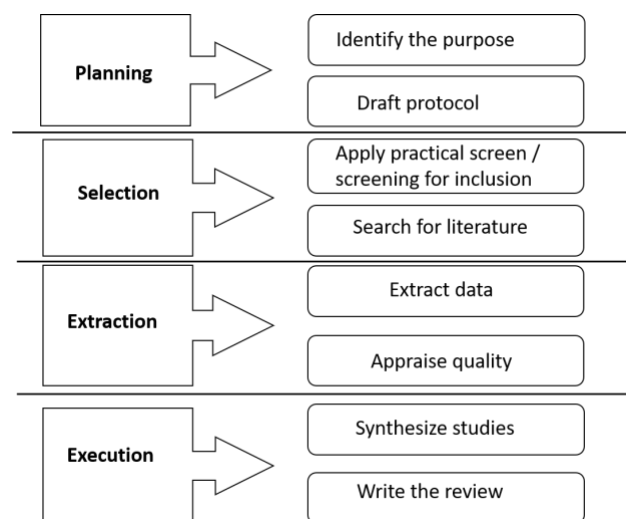


Figure 1. A systematic guide to literature review development followed

Source: Author based on Okoli (2015).

The planning phase had the following steps: determining the aim and purpose of the study and determining the research protocol. In the end, a synthesis of studies was carried out and a review was written.

For the purposes of the literature review, we initially used a time limit of 2008 to 2024. This is because the concept of "consumer neuroscience" appeared in 2008. In this defined period, the use of intelligent systems with varying degrees of sophistication in advertising was also developing. The emergence of the term "computational advertising" could not be precisely identified in time. The selection of studies took place in three steps. As part of the chosen search strategy, we first searched academic articles on Scopus, Web of Science, EBSCO, and Google Scholar. These electronic resources were chosen with regard to the topic of a systematic literature review dealing with computational advertising. In our opinion, it is reasonable to assume that most of the published literature on this topic is available in electronic form. Therefore, traditional sources of printed literature, magazines, and books were not included in this systematic literature review. Similarly, non-peer-reviewed sources such as theses, dissertations, popular media, monographs, websites, articles in progress, or unpublished articles were not included. The reason was our effort to compile a quality source of professional information for the professional public dealing with this area. There was also an effort to avoid all the risks associated with such resources that have not passed any quality standards check. A smaller number of studies were added as part of the backward reference search. First, articles were searched using query No. 1: "intelligent systems" AND "advertising". Furthermore, query No. 2 was entered: "consumer neuroscience" AND "advertising". Advanced query was used for all searches. Subsequently, a protocol was drawn up. An overview of the description of all performed searches, search strings, and number of results is given in Table 1.

Table 1. Overview of performed searches in sources, search strings and numbers of articles found

Source	Search mode	Time limit	Field	Search string	Number of articles found
Scopus	Advanced query	2008-2024	article title	TITLE-ABS-KEY(intelligent systems) AND TITLE-ABS-KEY(advertising) AND PUBYEAR > 2007 AND PUBYEAR < 2025	396
Scopus	Advanced query	2008-2024	article title	TITLE-ABS-KEY(consumer neuroscience) AND TITLE-ABS-KEY(advertising) AND PUBYEAR > 2007 AND PUBYEAR < 2025	137
Google Scholar	Advanced query	2008-2024	article title	intelligent systems; advertising	4
Google Scholar	Advanced query	2008-2024	article title	consumer neuroscience; advertising	15
Web of Science	Advanced search	2008-2024	article title	(TI=(advertising)) AND TI=(intelligent systems)	12
Web of Science	Advanced search	2008-2024	article title	(TI=(advertising)) AND TI=(consumer neuroscience)	6
EBSCO	Advanced search	2008-2024	article title	"intelligent systems" AND "advertising"	16
EBSCO	Advanced search	2008-2024	article title	"intelligent systems" AND "consumer neuroscience"	6
Total articles found					592

Source: Authors' own research.

The search led to finding a high number of articles (total: 592, query no. 1.: 428 and query no. 2.: 164) and therefore we decided to examine the studies by evaluating their abstract and conclusions. Criteria for the practical screen were established, as recommended in Okoli (2015). These criteria determined which studies should be considered for review and which should not. These criteria were sufficiently broad to enable the purpose of the article to be met. The content of the article therefore had to be focused on intelligent systems or consumer neuroscience and at the same time deal with their application in advertising or application in connection with advertising. The language of the publication had to be English. No restriction was given to the focus of the journals in which it was published or the authors. For the date of publication, the time limit was given above. The aim of the practical screen set up in this way was not to assess the quality or to evaluate the information found in the studies. Based on the above, articles that did not meet the above criteria were excluded in the second step.

Qualitative methodology, specifically qualitative synthesis, was used to synthesise the results. This is because both qualitative and quantitative contributions were found in the search results. This procedure is consistent with the delivery in Okoli (2015). The synthesis took place according to the recommendations of Webster and Watson (2002), in which all information from the previous steps of the systematic review was first collected and mapped. Subsequently, an evaluation was carried out with respect to the research questions RQ1 and RQ2, the objectives of the systematic review and also with regard to the prescribed structure of the review or article. The goal was to make it easier for readers to obtain information about and understand the topic, which is the role of intelligent systems and consumer neuroscience in computational advertising. Table 2 provides an overview of the criteria for the practical screen and the methodology used.

Table 2. Overview of used criteria for the practical screen and methodology

Information Sources	Scopus, Web of Science, EBSCO, and Google Scholar.
Publication period	2008 – 2024
Selected search strategy	The content of the article therefore had to be focused on intelligent systems or consumer neuroscience and at the same time deal with their application in advertising
Language of articles	English
Data synthesis method	Qualitative methodology, specifically qualitative synthesis. The collected information was evaluated with respect to research questions RQ1 and RQ2, the studied scope and objectives of the systematic review, the role of intelligent systems and consumer neuroscience in computational advertising.

Source: Authors' own research.

After screening, a total of 61 articles were included in this survey and some with a publication date before the originally intended limit (query no. 1.: 31 query no. 2.: 30) Finally, a total of 3 other academic articles found as a result of our backward reference search were added. A total of 64 articles were used for evaluation. The entire procedure of the search methodology is clearly shown on the PRISMA Chart in Figure 2. according to the methodology presented by Goug et al. (2017).

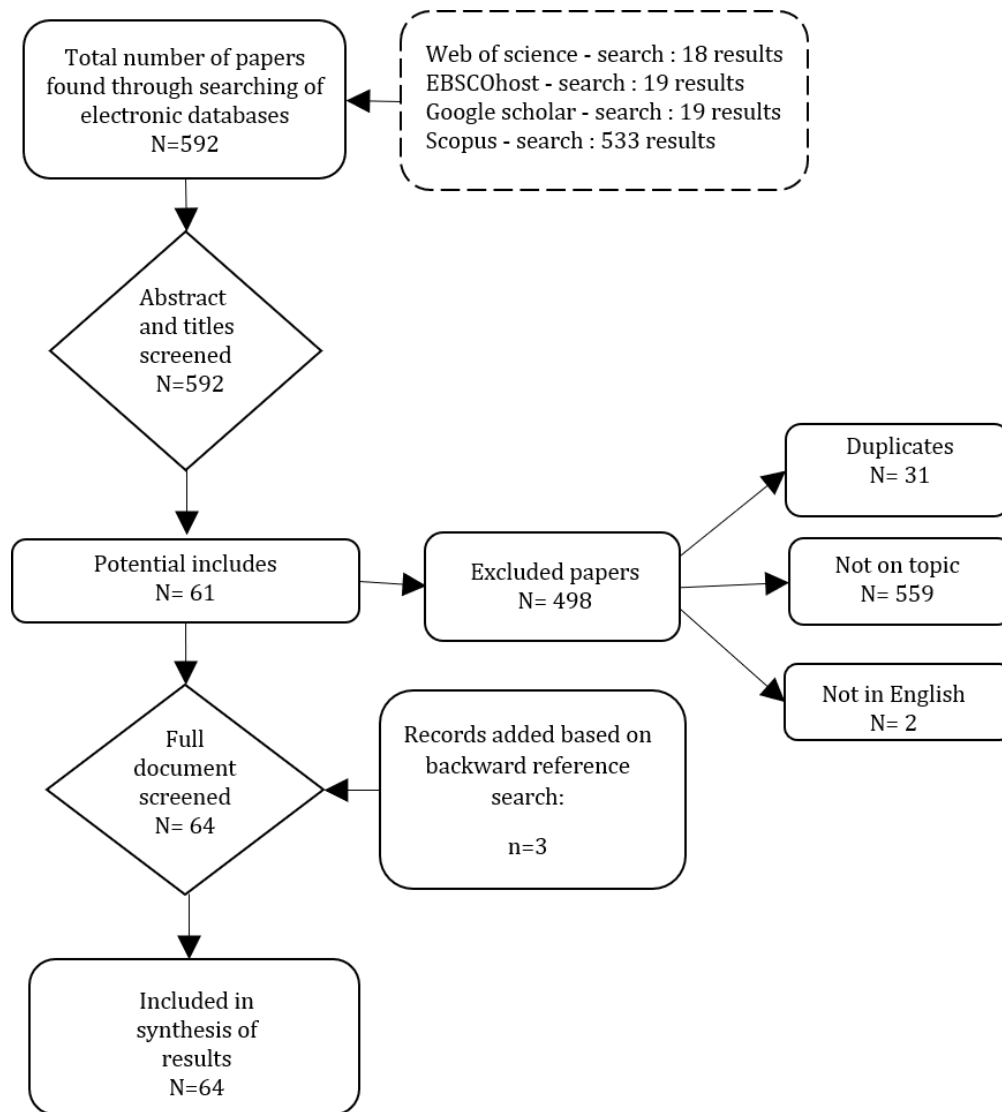


Figure 2. Overview of review methodology – PRISMA Chart

Source: Authors' own research.

Table 3 provides an overview of the year of publication of the articles selected for this article for both queries listed above.

Table 3. Number of publications that were selected for this study according to RQ questions and time of publication

	older	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
query no. 1	7	1	0	4	0	1	3	2	4	3	1	2	5	1
query no. 2	6	1	1	3	3	0	2	3	4	3	2	2	0	0
Total	13	2	1	7	3	1	5	5	8	6	3	4	5	1

Source: Authors' own research.

As a result, 64 articles corresponding to the questions were included in the final selection. The articles are from several fields, especially consumer neuroscience, neuroscience, marketing, psychology, economics, and computer science. Based on this review of selected studies, this article was created in order to achieve the goals of this review.

Table 4 provides an overview of the categorisation of articles according to the possibilities of individual information sources for both questions mentioned above. Some news sources classify articles into multiple categories.

Table 4. Number of selected publications by field category according to both queries

advertising and intelligent systems		advertising and consumer neuroscience	
Scopus		Scopus	
Computer Science	343	Business, Management and Accounting	55
Engineering	154	Social Sciences	30
Mathematics	84	Psychology	29
Decision Sciences	50	Neuroscience	28
Social Sciences	36	Economics, Econometrics and Finance	20
Business, Management and Accounting	19	Computer Science	19
Physics and Astronomy	16	Medicine	14
Energy	16	Engineering	9
Materials Science	11	Agricultural and Biological Sciences	6
Chemical Engineering	6	Mathematics	6
Medicine	6	Decision Sciences	5
Biochemistry, Genetics and Molecular Biology	5	Arts and Humanities	4
Chemistry	4	Biochemistry, Genetics and Molecular Biology	4
Neuroscience	4	Physics and Astronomy	4
Economics, Econometrics and Finance	3	Materials Science	3
Web of Science		Environmental Science	2
Computer Science Artificial Intelligence	2	Health Professions	2
Computer Science Cybernetics	1	Immunology and Microbiology	2
Computer Science Hardware Architecture	3	Multidisciplinary	2
Computer Science Information Systems	6	Pharmacology, Toxicology and Pharmaceutics	2
Computer Science Interdisciplinary Applications	1	Chemical Engineering	1
Computer Science Software Engineering	3	Chemistry	1
Computer Science Theory Methods	4	Energy	1
Engineering Electrical Electronic	1	Web of Science	
Mathematical Computational Biology	1	Business	3
Neurosciences	1	Communication	2
Telecommunications	1	Environmental Sciences	1
Transportation Science Technology	1	Environmental Studies	1
EBSCO		Green Sustainable Science Technology	1
advertising	2	Psychology Applied	1
advertisers	2	Psychology Multidisciplinary	1
algorithms	1	EBSCO	
automatic speech recognition	1	expert systems with applications	2

advertising and intelligent systems		advertising and consumer neuroscience	
cultural fusion	1	brain-computer interfaces	1
data mining	1	consumer behavior	1
decision trees	1	consumer preferences	1
electronic commerce	1	feature extraction	1
nonlinear regression	1	neuromarketing	1
outdoor advertising	1		
public transit	1		
systems design	1		
women executives	1		

Source: Authors' own research.

At the time of this systematic literature review, among the most cited articles regarding intelligent systems in advertising clearly belong to Guo et al. (2021), Guo et al. (2009), and also Aguilar & Garcia (2017). Among the authors or co-authors, Liu, K. and Liu, F. Among the most cited articles regarding the use of consumer neuroscience and advertising are Guixeres et al. (2017) and Sánchez-Fernández et al. (2021). From the authors or co-authors, Casado-Aranda, L.A., Cherubino, P.

Results

Today's advertising is one of the many communication forces that make up the current marketing communication spectrum, as stated by Casillas & López (2010). They state that the advertisement is paid for by the sponsor and serves to present his ideas, goods, or services that display the sponsor's brand or name. Advertising messages are delivered to the target group through various communication channels, especially through television, the Internet, magazines, and other media, as also discussed by Casillas and López (2010). According to Baker (2001), the aim of advertising is to create such a state of mind in the consumer that leads to a purchase. Many intelligent and digital technologies are used today to prepare, test, manufacture, deploy, and evaluate its effect.

Intelligent systems in contemporary advertising

The offer of intelligent systems for contemporary advertising, when we have at our disposal a large amount of data and also information in the form of so-called big data, is becoming more and more important both for the creator of the advertisement and for its sponsor. These systems make it possible to process and analyse data of various types and connect them in different ways. These systems make it possible to use data and information to create targeted ads that reach the right audience and increase the effectiveness of the advertising campaign. The search for patterns, contexts, and also the interpretation of these analyses provide an increasingly high-quality and qualified view of the creation and real deployment of advertising. To process the large amount of data and information that is currently available, it is necessary to use computer technology. It should be noted that not every intelligent system contains full-fledged artificial intelligence. So far, in practice, it is a symbiosis of a person and, to a certain extent, an intelligent system. But the main thing is that all complex analyses lead to a result that can be transformed into some form of marketing plan, business

plan or direct marketing action. Li (2019) emphasises that smart ads should be directly personalised according to the user's profile. These intelligent advertising systems provide a service beyond simply predicting a user's interests, needs, and wants in different contexts and time periods. However, the technical possibility of personalization entails a certain complication, in the form of the use of data about the user and the consequent need to obtain his informed consent. Artificial intelligence applications can be used throughout the consumer journey, as discussed by Kietzmann et al. (2018). In the field of advertising, they see the use of artificial intelligence in the process of creating rich consumer profiles, AI-enabled search results, ad targeting, predictive modelling, predictive lead scoring, content curation, AI-enabled monitoring of emotion, AI-chatbots in consumer support, dynamic CRMs, and content creation. Artificial intelligence can be used in the form of an implementation of an AI-driven advertising push system, based on natural language processing algorithms, which can have a number of useful applications in the field of advertising, as stated by Xin et al. (2023).

According to our findings, the use of intelligent systems in advertising can be divided into several to several phases of the advertising life. However, the individual phases partially merge with each other in order to ensure an effective and successful advertising campaign. The illustration is in Figure 3.

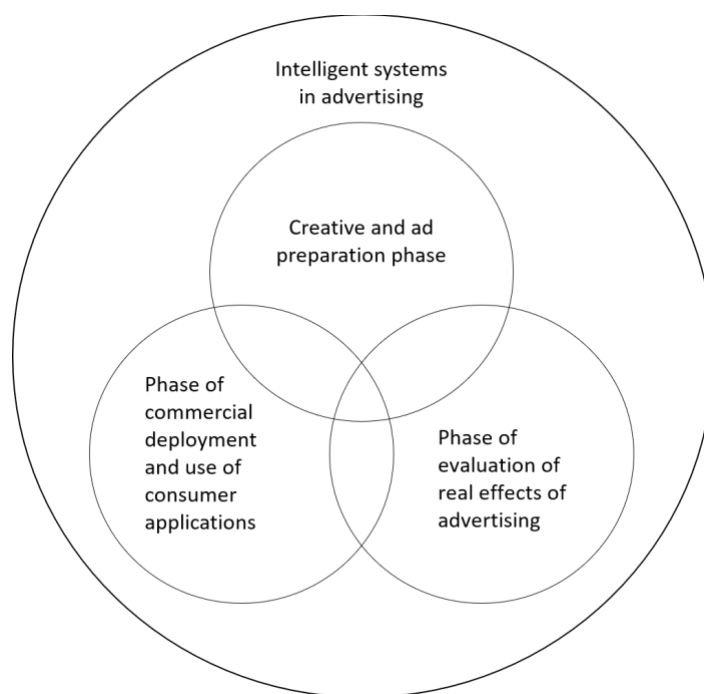


Figure 3. Overview of the found use of intelligent systems in contemporary advertising

Source: Authors' own research.

Creative and preparatory phase of advertising and intelligent systems

Already in the process of preparation and production of advertising, intelligent systems can be involved. Sophisticated computer systems with varying degrees of intelligence can be used to predict efficiency. Casillas and López (2010) mention the possibility of predicting customer response to new advertising, as well as the possibility of setting up targeted

advertisement campaigns and promotional activities using intelligent systems, and possibly systems powered by various forms of AI. Intelligent systems can also be used in the creative process in the preparation of marketing communication, as stated by Guo et al. (2021). They describe an intelligent system that supports creators in producing advertising posters and editing posters. An intelligent system related to digital advertising is also click prediction, as reported by Demirel et al. (2023). Helberg et al. (2020) mentions AI-driven consumer insights and advertising content creation.

Başev (2024) demonstrates extensive concrete use of intelligent systems in the preparatory and creative stages. He describes the creation of a Burger King ad using deep learning algorithms on big data and an artificial neural network. This ad used a script generated by artificial intelligence. Furthermore, he also gives the example of a TV ad for the Lexus ES that predicts driver intervention. This ad was written and directed by an AI. Başev (2024) also describes the use of IBM's artificial intelligence named Watson, which created the trailer for the horror movie "Morgan". He also describes the use of artificial intelligence to generate new content based on previous advertising for Cybercom group.

Stages of realisation of advertising and its commercial deployment and intelligent systems

Further involvement of intelligent systems can be done at the stage of advertising implementation and commercial deployment. The area of digital advertising is very current, and it actually makes up a very large part of current advertising activities. According to Adams (2004), intelligent systems in advertising are central to the possibility of using their interactivity, personalization, and general usability for marketing. Furthermore, Adams (2004) particularly highlights the use of artificial intelligence and smart systems applicable in the field of advertising. He also draws attention to the new content forms that these technologies bring. Today, websites, digital television, mobile and wireless platforms actually serve as the market place for customers and compete strongly with older "analog" platforms. New sales and marketing media allow advertisers to communicate without barriers directly to consumers at the time of sale, both in writing, visually, and acoustically. Thanks to these technologies, advertising messages can be delivered at the optimal time and context, which increases the probability of success of the advertising campaign. Adams (2004) also states that these systems make it possible to use advanced technologies such as natural language processing, machine vision, and intelligent data retrieval for the dissemination of advertising and its message. He sees the perspective mainly in interactivity, personalization, and general usability for marketing. Boermann et al. (2017) mention monitoring people's online behaviour and based on that on the production of online behavioural advertising. The use of intelligent systems and artificial intelligence is also possible in consumer applications.. Intelligent systems can be used in digital marketing, namely autonomous intelligent systems that are compatible and work integrated with the Google Ads platform, as discussed by Pak et al. (2018). The aim of the applications is to perform estimations to optimise ROI, conversions, ad texts and profits. Automated and intelligent advertising systems can also be used in the field of sponsored search in Internet applications, as stated by Yang et al. (2019). They also discuss the important issue of intelligent targeting and models for this issue. Chapelle et al. (2014) discuss intelligent systems in the context of conversation rates estimation and clickthrough. Intelligent systems for these calculations perform core predictions tasks when using digital display advertising. In the field of digital advertising, intelligent systems are used that enable the personalization of advertising messages and

their delivery directly to the end user. Casillas and López (2010) describe interactive advertising and the optimisation of advertising campaigns of various kinds. They emphasise the innovation of advertising themes, the use of expert systems, the use of data mining, and intelligent targeting of advertising. The goal is reaching the customer in a way that can currently be considered new or innovative, generally attractive, and also unique. Anagnostopoulos et al. (2011) describe methods of intelligent analysis of the entire content of a web page and methods of optimising displayed advertising. Digital primary models of Internet advertising can also be classified as intelligent systems. In this context, Bae et al. (2003) discuss the possibility of using the so-called "fuzzy reasoning" methodology. These models mainly include banner ads, sponsorship, e-mail communication, communication on chats, and also push technologies. The goal is to optimise ad targeting. Ha (2004) also described an intelligent Internet advertising targeting system using fuzzy inference and data mining methodology. Bauer and Novotny (2017) describe an extensive overview and analysis of context models using intelligent systems that are aware of their context and can adapt their behaviour accordingly. Yang et al. (2019) deal with sponsored search advertising, which is a long-standing hidden form of advertising and uses intelligent search engines working with an automated bidding strategy and intelligent targeting. Yang et al. (2019) also deal with the intelligent use of keyword assignment, keyword targeting, and keyword grouping intended for campaign target groups of advertisements. Bauer (2014) deals with intelligent context-adaptive systems, which is intended to increase sales and uses specific contextual advertising and scenario context-adaptive advertising messages. Intelligent systems in advertising can also be used in the offline world, namely intelligent billboards targeted advertising systems by incorporating Internet of Things (IoT) and Internet of Behavior (IoB) technologies into Out Of Home Advertising (OOH) as reported by Khalil et al. (2023). Liu (2023) deals with intelligent advertising recommendation using machine learning combined with artificial intelligence, which represents a complex integration of technologies and can significantly improve the precision and effectiveness of digital marketing.

Başev (2024) describes an application of an intelligent system by Netflix that offers movie recommendations to individual consumers based on their favourite movies and on the basis of an analysis of their behaviour on the Web. He further describes similar systems by Facebook and Instagram.

The phase of evaluating the real effects of advertising and intelligent systems

The involvement of intelligent systems can also be done in the phase of evaluating the real effects of advertising. Neural networks can be used to analyse the effects of advertising and promotion on sales, as reported by Poh et al. (1998). Sun (2022) presents an intelligent offline outdoor advertising effect evaluation system based on facial gesture recognition to calculate pedestrian ad viewing rates. The system also analyzes and recognizes different pedestrian movement trajectories.

The practical application of AirBnB's intelligent advertising system is described by Başev (2024). The system, which uses machine learning, evaluates and analyses the features and location of properties, aims to offer users the best deals on homes with optimised prices in real time. He further describes Harley Davidson's AI-powered Albert software that helps determine marketing campaigns and strategies and also recommends advertising activities.

Mobile advertising and intelligent systems

Some authors understand mobile advertising as a separate area. In the field of mobile marketing, Evans et al. (2012) describe intelligent systems and intelligent advertising services and discuss the use of components of the system of global positioning system, whereby the information received by a member of the target group contains contextual information and intelligent context-oriented advertisements targeted according to the current location. Pham and Wang (2019) describe the use of intelligent systems in mobile advertising to understand the emotional responses of target audiences to video advertising. The goal is to track and quantify the effects of mobile video advertising in real time. For monitoring, Pham and Wang (2019) describe a combination of facial expression analysis and implicit photoplethysmography that evaluates viewers watching video ads on unmodified smartphones.

Advertising in virtual reality and intelligent systems

Intelligent advertising also finds application in virtual reality. The goal is to use virtual reality in the advertising industry, both in the design process and in the actual use in the communication process. Qin and Lei (2019) discuss the use of various applications in virtual reality advertising and communication.

Generative artificial intelligence in advertising

Generative artificial intelligence is currently a very young and rapidly developing technology that is quickly finding its way to application in advertising. Generative artificial intelligence is part of a family of intelligent and AI-based systems. As stated by Gao et al. (2023), the affordability threshold for generative artificial intelligence technology, and therefore artificial intelligence in general, has been significantly reduced. Gao et al. (2023) states that they consider targeting, personalization, content creation, and Ad optimisation to be the basic key pillars of AI advertising as part of computational advertising. According to them, generative artificial intelligence can also be used to analyze information about consumers. Başev (2024) highlights, among other things, the ability of generative artificial intelligence to simulate human intelligence and react similarly to humans based on the information provided to the AI. In advertising, he cites chatbots in website chat windows and customer service agents in various industries as examples. Gao et al. (2023) and Başev (2024) state that generative artificial intelligence finds application in the generation of diverse and rich advertising content, and its use increases creative quality and ad impact. They also indicate its use, including examples in the creation of personalised advertising messages, copywriting or editing tasks, the possibility of creating various media forms, images, video and written text, and also enables direct interaction with individual users based on the analysis of their consumer behaviour and preferences in real - time. Leszczynski et al. (2022) provide a very detailed and comprehensive list of jobs and tasks for which generative AI is used in advertising agencies. This is work in the field of coordination of work, data analysis, communication and customer service, creative works, market research, optimisation of advertising activities, and strategic planning.

Figure 4 shows an overview of the use of intelligent main systems in contemporary advertising, as found in this systematic literature review.

Applications of intelligent systems in advertising		
preparation and production of advertising	realization of advertising and its commercial deployment	evaluation of the real effects of advertising
advertising design prediction of creative effects gathering consumer insights creation of advertising content effectiveness prediction use of data mining intelligent targeting innovative advertising themes predicting customer response setting up targeted campaigns rich consumer profiles predictive modeling AI-enabled emotion monitoring content creation	ROI optimization estimates conversion and profit estimates intelligent sponsored search Clickthrough estimates personalization of messages interactive advertising optimization of campaigns fuzzy reasoning, fuzzy inference sponsored search advertising keyword assignment context-adaptive systems specific contextual advertising context-adaptive messaging recommendation systems advertising in virtual reality mobile advertising content curation AI-chatbots consumer support dynamic CRMs AI-driven push system	Neural networks analysis of advertising effects optimization of campaigns analysis of context models evaluation of the effect click prediction process predictive lead scoring

Figure 4. Overview of the found use of intelligent systems in contemporary advertising

Source: Authors' own research.

Advertising and consumer neuroscience

Technologies for collecting data on target groups of consumers and their evaluation are part of the intelligent systems that can be used in the process of creating advertising. Among relatively very objective digital or digitalizable measurements, certainly belong to the technologies used in consumer neuroscience or neuromarketing. These methods are used in both the process of preparation and the evaluation of advertising. Huh and Malthouse (2020) already raised the question of how to apply and implement computational approaches to advertising research. Also, Alvino et al. (2020) discusses the use of data evaluation in the field of advertising. Given the digital or digitizable character, consumer neuroscience methods are certainly one way to achieve this. This path is also consistent with the opinion of Yun et al. (2020) on measuring advertising effectiveness. Also, Helberger et al. (2020) talk about the need for data collection and their analysis within the new form of the advertising industry and the concept of computational advertising. They mention the possibility of detailed targeting, planning, and based on that media buying through artificial intelligence. Sestino and De Mauro (2022) note the use of AI applications in the neurosciences. Artificial intelligence is used as a consumer neuroscience research tool, sometimes with a built-in survey tool. Van Noort et al. (2020) discuss at length the need for quality consumer data that is obtained in an ethical and legally transparent manner, consistent with privacy protections,

and with an emphasis on empirical research and content that is based on consumer data other than behavioural data. According to them, the goal is to include in this computer concept empirical research on consumer attitudes and perceptions, attitudes toward advertising, trust or skepticism toward advertisements, expectations from advertising, and also advertising transparency. Consumer neuroscience methodologies and techniques can be combined with demographic data, behavioural data, and psychographic data. Use of methodologies and techniques offered by consumer neuroscience or neuromarketing as an intelligent system, including applications of artificial intelligence, can be considered usable within the concept of computational advertising.

The use of neuroscientific methods and techniques provides a new way to map cognitive processes. Cognitive and affective processes underlying consumption decisions. Venkatraman et al. (2012) states that these methods enable a better understanding of the neural mechanisms of decision making. Piwowarski et al. (2019) mentions that consumer neuroscience or neuromarketing as a cognitive neuroscientific method can be used to support in the process of advertising design, more detailed analysis of people's reactions to stimuli, and obtaining information about their potential interest. Furthermore, it is possible to use these methods to monitor the recall or emerging emotions and adapt the content of the advertising message accordingly. Gala and Gligor (2022) state that neuromarketing can provide new information about human preferences and emotional reactions arising in the process of viewing, consuming, or evaluating different types of advertising. They state that consumer neuroscience or neuromarketing methods can be used to better understand brand preference, advertising effectiveness, customer attention, and also to understand cognitive and emotional responses to advertising stimuli. According to them, these methods can also be used in the field of branding to understand physiological reactions to brand placement, brand enhancement efforts, brand communication, and other related brand efforts.

Alvino et al. (2020) deal with the popularity of using individual neuroscientific methods. Based on their own research, they found that currently the most popular neuroscience tool is electroencephalography (EEG), which is used by approximately 60.5% of researchers alone or in combination with other tools. The second most used tool is Eye tracking (ET) in approx. 17.5% of cases. It is followed by functional magnetic resonance imaging (fMRI) with approx. 14.5%. Then facial expression recognition software (fERS) was almost 9.5%, galvanic skin response (GSR) 8%, functional near-infrared spectroscopy (fNIRS) almost 6.6%, and electrocardiogram (ECG) about 5%.

Consumer neuroscience techniques applicable to advertising

Several neuromarketing tools can be used to analyse advertising or branding. These are mainly facial expression recognition, eye tracking, electroencephalography, but also electrocardiogram or functional magnetic resonance imaging, as stated by Alvino et al. (2020). Harris et al. (2018) complete the list of applicable tools and mention magnetoencephalography, steady-state topograph, and heart rate measurement.

Eye tracking

Eye tracking is a very frequently used methodology in the field of advertising testing. Sánchez-Fernández et al. (2021) reports the use of this technique for the utilisation of media elements of advertising design as well as animation in conjunction with pupil size or pupil dimensions measurement. Nakagawa (2011) also mentions the use of eye tracking to analyse

and testing the effects of advertising and adds the possibility of combining this methodology with EEG. Harris et al. (2018) mention the use of eye tracking for testing print messages, advertising in the form of static images, advertising in social media, analysis of web pages, and website optimisation, but also as an alternative to testing TV advertising, video spots or video advertising in general. O'Connell et al. (2011) describe the use of eye tracking in the development and evaluation of advertisements, concept testing, logo designs, packaging, online environments, television advertising website development, and outdoor advertising.

Electroencephalography

Electroencephalography is a method that is very often used in connection with advertising and is not technically demanding. According to Harris et al. (2018) this method can be used especially for testing video ads, TV ads, film ads, audio ads, print messages, ads in social media, ads on web pages and website optimisation, ads in the form of static imagery for all applications. Ciorciari et al. (2019) report the use of electroencephalography to investigate the brain response associated with the evaluation and processing of commercial advertising information and the evaluation of emotional intelligence. Ohme et al. (2009) described the use of electroencephalography to evaluate the effects of TV advertising.

Electromyography

Electromyography / facial expression recognition software is based on the use of elements of artificial intelligence in combination with the natural reactions of the human body. It is a completely non-demanding technique for the respondent. Lewinski et al. (2014) cite this technique as a useful diagnostic tool for evaluating advertising effectiveness, as well as understanding the causes of varying degrees of effectiveness. According to Harris et al. (2018), facial expression recognition software is especially useful for testing the likeability of video ads, still images, and audio ads. According to Sung et al. (2020), this technique is suitable not only for emotionally expressive advertisements but also for identifying attitudes towards advertising, attitudes towards the advertised brand and also for capturing amusement in response to advertising. Hamelin et al. (2017) draw attention to the issue of the sensitivity of this method. They found that high-emotional advertising generated higher and longer-lasting results compared to low-emotional advertising. According to them, however, the relationship between emotion and the human cognitive process is unclear.

Galvanic skin response

Galvanic skin response is a simple technique that is not demanding at all. It is often used in combination with other consumer neuroscience methods. It can be used in research in the field of video advertising, TV advertising, video spots, audio advertising, advertising on web pages and in social media. It can also be used in advertising research in the form of static imagery and print messages, as reported by Harris et al. (2018).

Electrocardiogram

Another non-technologically demanding method is the electrocardiogram, which is often used as an additional reaction monitoring in combination with other consumer neuroscience methods. This methodology finds, according to Harris et al. (2018), an application in the research of TV commercials, video commercials, video spots as well as for the research of print messages, advertising on web pages and in social media, advertising in the form of static

imagery and audio advertising. Diao and Sundar (2004) describe the use of an electrocardiogram to test an online portal website and banner advertisement.

Heart rate measurement

Heart rate measurement is also a simple and commonly used biometric technique. Harris et al. (2018) list its use in advertising for almost all areas. It can also be used as a wearable device outside of laboratory conditions and spaces, or in combination with other consumer neuroscience methods. Also Sánchez-Fernández et al. (2021) recommend the use of a heart rate combination in combination with an electrocardiogram for measurements in the field of online advertising and also environmental advertising.

Functional magnetic resonance imaging

This neuroscience technology is technically quite challenging. It has a technically limited use, which is based on the nature of the respondent's response processing technology. Harris et al. (2018) state use only for research on print messages, static imagery and images, and research on packaging.

Magnetoencephalography

Magnetoencephalography is also a technologically demanding research technique. Sánchez-Fernández et al. (2021) report its application in the field of monitoring evoked and affective reactions to audiovisual advertising. According to Harris et al. (2018) is, however, applicable in the research of TV advertising, film advertising, video advertising, video spots, radio advertising, audio advertising and audio spots in general, as well as research and testing of print messages, web stands, static images and advertising on social networks.

Steady-state topograph

Last but not least, the steady-state topograph is used in the field of advertising research. Silberstein and Nield (2008) describe the use of brain activity measures to examine the relationship between television advertising and changes in consumer brand preference, advertising effectiveness, and branding. Harris et al. (2018) mention the use for testing the likeability of both static images, audio-advertisements and video advertisements of all kinds.

Mixed Methodology

A combination of various consumer neuroscience methodologies is very often used in practice in the field of advertising, in which case we speak of a mixed methodology. The goal is to achieve greater accuracy of the measurement results. Guixeres et al. (2017) report the use of a combination of eye tracking, heart rate variability, and electroencephalogram. Harris et al. (2018) report a combination of electronic encephalography and eye tracking that brings cost reduction. Clark et al. (2018) describe mobile advertising research using a combination of eye tracking during the user experience simultaneously with tracking of visual fixations, heart rate, electroencephalography, skin conductance, and combined with evaluation of facial reactions. Ausin-Azofra et al. (2021) describe the use of a combination of neuroscience methods to test the effectiveness of 360-degree video digital advertisements. Table 5 provides an overview of the found use of intelligent systems in contemporary advertising.

Table 5. Overview of the described use of consumer neuroscience methods in current advertising

Neuroscience tools	Found use in contemporary advertising	Found use in combination with other methods	Sources
Electromyography (facial recognition)	evaluation of advertising effectiveness, testing of liking of video advertising, testing of attitudes towards advertising, attitudes towards the advertised brand, testing of static images and audio advertising, identification of entertainment	Yes	Hamelin et al. (2017), Sung et al. (2020), Harris et al. (2018), Lewinski et al. (2014), Clark et al. (2018)
Eye tracking	Optimisation of media elements of advertising design and animation, testing of print messages, testing of static images, advertising in social media, testing and analysis of web pages, website optimization, testing of the online environment, testing of TV commercials, video spots, testing of concepts, testing of logo designs, packaging testing , outdoor advertising	Yes	Sánchez-Fernández et al. (2021), Nakagawa (2011), Harris et al. (2018), O'Connell et al. (2011), Guixeres et al. (2017), Clark et al. (2018)
Electroencephalography	Testing of video ads, TV ads, film ads, audio ads, print messages, ads in social media, ads on web pages and website optimisation, ads in the form of static imagery, evaluation and processing of commercial advertising information	Yes	Harris et al. (2018), Ciorciari et al. (2019), Ohme et al. (2009)
Galvanic skin response	Research into video advertising, TV advertising, video spots, audio advertising and web pages, social media, static imagery and print messages	Yes	Harris et al. (2018), Clark et al. (2018)
Electrocardiogram	testing TV ads, video ads, video spots, print messages, web pages, test banner ads, social media, static imagery, audio ads	Yes	Harris et al. (2018), Diao and Sundar (2004)
Heart rate	testing TV ads, film and video ads, audio advertising, print messages, social media, static imagery, packaging, online advertising, environmental advertising	Yes	Harris et al. (2018), Sánchez-Fernández et al. (2021), Guixeres et al. (2017), Clark et al. (2018), Fortunato et al. (2014)
Functional magnetic resonance imaging	Testing of print messages, static imagery, and pictures, research on packaging	not found	Harris et al. (2018)
Magnetoencephalography	affective response testing and testing of audiovisual and TV advertising, film advertising, video advertising, video spots, radio advertising, audio advertising,	not found	Sánchez-Fernández et al. (2021), Harris et al. (2018)

Neuroscience tools	Found use in contemporary advertising	Found use in combination with other methods	Sources
	research and testing of print messages, web stands, static images, and advertising on social networks.		
Steady-state topograph	testing TV commercials, advertising effectiveness, branding, branding	not found	Silberstein and Nield (2008), Harris et al. (2018), Wang and Minor (2008)

Source: Authors' own research.

Other current consumer neuroscience tools

For the sake of completeness, it is also necessary to mention the remaining tools of consumer neuroscience, which have not yet found application in the field of advertising. According to Harris et al. (2018), this is transcranial magnetic stimulation with very limited use in the area of decision-making research. Next, positron emission imaging, functional transcranial Doppler sonography.

Practical applications of selected consumer neuroscience tools

The use of neuroscientific research is aimed at analysing how consumers experience, process, and evaluate advertisements. Alvino et al. (2020) describe a broad overview of specific applications of consumer neuroscience research in advertising. Astolfi et al. (2008) describe the practical use of the most commonly used advertising tool, the electroencephalogram (EEG). EEG evaluates brain responses to evaluate the memorability of TV commercials over several days. Venkatraman (2015) deals with the practical prediction of advertising success. They use a combination of several methods to measure both traditional self-reports and implicit measurements of eye tracking, biometrics, electroencephalography, and functional magnetic resonance imaging. Guixeres et al. (2017) describe the use of consumer neuroscience methods to predict recall, liking, and viewing rates in online advertising. The technique used was brain response, heart rate variability, and eye tracking. This combination can be used already in the design stages of advertising content, and thus can increase the effectiveness of advertising.

Discussion

On the one hand, the current trend of general digitisation in all fields can lead us to believe that the current concept of advertising in the spirit and meaning of the collective term computational advertising (Huh & Malthouse, 2020; Yang et al. , 2017) is and will be also crucial in the future. It is true that this concept represents, if not the future, then certainly a long-term perspective for the entire advertising ecosystem. On the other hand, not all of these intelligent systems are perfect and their integration and interconnection are currently lacking. So far, there are only defragmented or partial, more or less, intelligent systems usable within the early stage of advertising preparation. These ad preparation systems have been extensively described (Alvino et al. 2020; Demirel et al., 2023; Guo et al., 2021; Ha, 2004;

Piwowarski et al., 2019; Qin & Lei , 2019). These are systems supporting the creation of advertising, its creative and advertising targeting. This undoubtedly includes many consumer neuroscience technologies. Also, there are only partial intelligent systems applicable to commercial deployment of advertising (Adams, 2004; Bae et al., 2003; Bauer, 2014; Casillas & López, 2010; Li, 2019). These are mainly operational systems aimed at optimising advertising campaigns, campaign management, and intelligent context adaptive systems. Finally, there are also only partial intelligent technologies for advertising evaluation (Chapelle et al. 2014; Pham & Wang, 2019; Poh et al. 1998). These are especially intelligent systems evaluating conversation rates, evaluating the effects of advertising in real time or after its deployment.

Several authors (Helberger et al., 2020; Zuboff, 2023; Nissenbaum and Daniel, 2009) also point to ethical issues, existing large-scale consumer surveillance, and the dangers of behavioural profiling of individuals used for enhanced personalised advertising. These smart technologies are already supported by artificial intelligence today and are quite powerful. However, the risks of using intelligent systems are both on the side of users and also on the side of advertisers and the advertising industry. The most frequently discussed risk and concern in connection with computing advertisement is the misuse of personal information in various forms and forms. Helberg et al. (2020) literally state that consumer data are indeed considered a new oil, currency, and power in the today's advertising ecosystem. They also state that advertisers and advertising firms collect information about individual consumers by tracking consumers' online behaviour over time. Helberg et al. (2020) specifically provide examples of IoT products that actually function as risky data collection points. Zuboff (2023) describes a case from 2000 dealing with the existing possibilities of ubiquitous electronic surveillance and data collection in the home environment in a controlled experiment. The outcome was the finding that the personal data obtained in this way threaten personal privacy to a very large extent, while even very sensitive health data was monitored. The commercial use of data obtained in this way for various and also advertising purposes obviously has enormous financial potential, but it represents a real risk. Yun et al. (2020) also draw attention to new negative phenomena related to computational advertising, such as ad fraud, creeping out customers, and fake data. Fulgoni (2016) describes how computers can become infected with malware from infected advertisements on websites and turn into fraudulent robots. The whole area of computer advertising probably needs more legal regulation. This new legislation should protect both users and the advertising industry and advertisers. Currently, the necessary strengthening of the importance of the role of GDPR standards, the new regulation of artificial intelligence applications in Europe and the newly forming regulatory regulations for the use of artificial intelligence in other countries come to the fore. But it is a question whether the legislative process will be flexible and fast enough to be a sufficient answer to all the risks, ethical dilemmas in this dynamic industry. Despite the reservations of some authors, it seems that the direction of development represented by gradual integration and the growing importance of these intelligent systems in advertising is correct and meaningful.

It may also seem that the importance of consumer neuroscience research tools in the field of advertising will grow. Several researchers positively evaluate the progress and current state of consumer neuroscience not only in the field of advertising. Many are excited about the potential of consumer neuromarketing and its potential contribution to research practice. Precourt (2015) states that it is absolutely certain that neuroscience will be an

integral part of the future of marketing research, as well as academic research. Fugate (2007) believes that the power of neuromarketing is that it can uncover subconscious biases that traditional advertising methods cannot. Camerer and Yoon (2015) confirm the addition of neuroscientific methods to the researchers' standard toolbox. Piwowarski et al. (2019) state that these methods enable a more detailed analysis of people's reactions to the presented stimuli, obtaining information about their interest, remembering the advertising message or emerging emotions in respondents in real time. de Balanzó and Sabaté (2007) see the perspective of this type of research on the human brain as an opportunity opening up new possibilities in the field of consumer surveys for and their application in marketing and advertising. Page and Raymond (2006) consider cognitive neuroscience to be a powerful tool and indicator of advertising success. On the other hand, it cannot be overlooked that some researchers remain somewhat cautious and skeptical. Fugate (2007) deals with current issues and future direction of consumer neuroscience. According to him, a number of researchers present their concerns regarding both methodology, as well as concerns about research ethics, and concerns about certain groups of consumers. Also, de Balanzó and Sabaté (2007) reflect on the ethical limits of neuromarketing. There are many ethical questions that arise in connection with the application of neuromarketing. According to them, the most important are the interference with the privacy of individual research subjects. Furthermore, the fact that the knowledge gained in this way can be massively used or possibly abused to influence the purchasing intentions of consumers or society as a whole. Their warning against the plausible manipulation of the data obtained in this way is also important. Likewise, Ramsøy (2019) criticizes methodological differences, conceptual inconsistencies, lack of systematic validation of neuroscience metrics, and dubious business practices. Varan et al. (2015) calls for greater transparency of neuroscience research and emphasises the current lack of standardization and the prevailing emphasis on individual solutions. Despite all the problems related to the rapid development of consumer neuroscience in recent years, demonstrably great successes have been achieved in the development of this methodology. Precourt (2015) states that the development of consumer neuroscience brings a dilemma only in choosing the appropriate methodology, but not the function. According to de Balanzó and Sabaté (2007), neuromarketing still retains its main goal, which is to improve the effectiveness of advertising. A reasonable compromise is probably the opinion of Page and Raymond (2006), who state that we will see improvements in this methodology in the future.

Some tendencies can be observed in the cited papers and the topics. Trends in the digitisation of neuromarketing and the use of intelligent systems are generally received relatively positively. The same is the case with the ongoing process of computational advertisement formation. These processes are not fundamentally contradictory. Furthermore, it can be stated that there is a relatively large number of partial criticisms on various partial problems. This is probably due to the rapid and very rapid development of this entire high-tech area. It can also be stated that there is a positive expectation that these technologies will increase quality, speed, and reduce costs in all the processes and uses concerned. This expectation is also confirmed by the described examples of practical applications. Also, the real complexity and complexity of the highly advanced technologies discussed, nor their reliability or cost, are not discussed. In general, this development can perhaps be considered progressive. However, there is probably a long way ahead of us, the goal of which is the gradual improvement, improvement and standardisation of these systems and their subsequent integration.

Conclusion

The advent of intelligent systems and artificial intelligence have significantly changed the entire field of advertising recently. This article provides an overview of the current possibilities of use and characteristics of both intelligent systems and neuroscience tools used in the field of advertising. Based on a systematic literature review, we found and described the entire range of current technologically advanced intelligent systems and consumer neuroscience tools and analysed the possibilities of their deployment in the field of advertising. These systems and tools already today affect all phases of the advertising life cycle and influence both creation, preparation, testing, production, and the manner and form of commercial deployment of advertising and its evaluation. All phases of advertising life and the way such intelligent systems are used are closely related. The classic division into the area of preparation, production, media deployment, and evaluation of the effects of advertising and desired sales is gradually merging. The concept of computational advertising (Huh & Malthouse, 2020; Yang et al., 2017) is thus taking on concrete contours. It appears that this is only the beginning of this process, as these dynamically developing computer systems and applications are clearly only at the beginning of their evolution in these areas. It also follows from the systematic literature review that the development will probably move towards the gradual integration of these systems into more or less autonomous applications covering larger parts or the entire process of creating and living advertising. Although today these systems and tools are diverse and fragmented, the current offer and availability of a wide range of intelligent systems and related consumer neuroscience tools allow users to choose the necessary and effective tool to solve a given problem at every stage of the advertising life cycle. These options are to the benefit of both quality and effective advertising, as well as to the benefit of the consumer and advertisers.

In relation to the first research question, the aim of which was to identify intelligent systems that can be included in the concept of computational advertising, it can be stated that a whole spectrum of modern technologies was found that allow the contracting authorities to correctly select the target group, technologies that support the creative phase and the preparation of advertising, enabling the acquisition of relevant data for decision-making about the content, message, and form of advertising, tools for testing advertising, tools for commercial deployment, calculations of estimates of financial effectiveness up to tools for the final evaluation of its real effectiveness. The deployment of these intelligent systems is currently possible both in online and offline advertising. It is a true symbiosis of technologies, the goal of which is to achieve optimal advertising with maximum effectiveness so that advertising is effective not only from an economic point of view but also from a sociological-marketing point of view. However, these new technologies still require the cooperation of a person, both in the creative, computational, and economic stages, as well as in the position of decision maker. This is a spectrum of different digitised systems, from narrowly specialized to systems with varying degrees of complexity. These are technologies with varying degrees of intelligence up to applications using so-called artificial intelligence. These are applications with varying degrees of autonomy or automation of processes that include both economic, marketing and marketing research processes and knowledge so that the design, real use of advertising, and its effect are optimal.

Regarding the second research question, which set itself the task of finding which of the current consumer neuroscience tools find application in the current computational advertising trend, we can also state that we found a large number of such tools. These tools

can be used both in the testing phase, creating the basis for deciding on the selection of advertising, evaluating its effects, and also partly during its deployment. Consumer neuroscience tools provide a new depth of understanding of how consumers subconsciously respond to advertising in real time, while these technologies integrate elements of classic neuroscience, consumer psychology, and insights into consumer decision-making. Current consumer neuroscience tools certainly have the potential to change advertising for the better and more objective, especially due to the objective nature of the principles of operation of these tools. Consumer neuroscience is slowly but surely becoming part of the process described as computational advertising. This is especially so because these tools are also digital or digitizable, and their outputs can be effectively applied in a chain of interrelated, already digitised, sophisticated activities of the computational advertising concept. However, much more needs to be done in order for consumer neuroscience techniques to be sufficiently credible, standardized, and to resolve all existing methodological gaps. Also, there is still a whole range of emotions that have yet to be captured and subsequently described.

Our findings show that both technologies, both intelligent systems and consumer neuroscience, can be digitally integrated in the future. It is already certain today that this path taken brings a new level of process quality within the framework of advertising creation, its implementation, relevant knowledge about advertising, but also the understanding of its meaning by the client and the consumer. Therefore, it is a challenge for both academics and advertising professionals to make full use of the potential of both technologies and the potential of their possible integration.

The main contribution of this article is the systematic mapping of the application of various types of intelligent systems falling under the concept of computational advertising in individual phases of the advertising life cycle. Another contribution is a clear identification of consumer neuroscience tools applicable in the concept of computational advertising and a direct description of its usability and implementation possibilities. We believe this study provides a comprehensive overview of consumer neuroscience tools and intelligent systems in advertising that can be put to practical use by researchers and professionals in the field. Furthermore, we believe that this work will allow potential interested parties to deepen their knowledge in this area and possibly allow them to follow up on this topic with their own research, article, or publication. This article opens up the possibility of supplementing the research with applications applicable in the computational advertising concept for the area of purchasing advertising and measuring the effectiveness of the sale of advertised products, as well as deepening the systematic categorisation in the areas studied above.

This systematic literature review was developed with the aim of basic mapping of the current rapid and exciting process of digitization of advertising and related areas. But it is not possible to affect everything and all opinions. The article tries to cover the trends currently described and analyze the basic connections between individual issues. The list of issues in the article is certainly not exhaustive. Another limitation is that we only considered publications in the English language. Also in the field of ethical and moral consequences of the use of intelligent systems and tools of consumer neuroscience, there are still many unresolved issues, questions, and moral dilemmas that relate to the use of personal data of respondents, big data, and applications of artificial intelligence.

The future directions of research in this area are largely dependent on the rapidity of development in the studied areas. However, there are already identifiable gaps in the current literature that future research could fill. It is already clear today that artificial intelligence

will be a significant driver. So far, there is little literature on the role of AI in this area. It is still a question of whether and to what extent AI will help in the integration of all systems within computational advertisement. It is also possible that AI will indicate, determine, or even create new directions, new areas of use, and application of technologies in this area. Future research could address the role of AI in the areas of interest. Another gap in the current literature is the integration of intelligent systems and neuroscience in practical applications within computational advertisement. . There is a dearth of literature devoted to this topic. There are more or less conceptual descriptions or visions of how computational advertising works. There is also probably room for future research here. The question of the ethical consequences of using both intelligent systems and neuroscience tools in computational advertising will certainly remain open for a long time. However, in parallel with the development of these technologies and their applications, new ethical questions and dilemmas will arise that do not yet exist. Research in this area is certainly an opportunity for new research. So it looks like we are in for a tumultuous period of further development in this whole area.

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