

Strategies and guidelines for the aesthetic design of QR codes in advertising

Estrategias y directrices para la configuración estética del QR en publicidad



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Abstract:

QR codes are sometimes used as a vital component of digital marketing strategies that seek to attract consumers' attention by converting their dull, black-and-white, checkered appearance into attractive designs. However, as changes to their visual appearance can lead to scanning failures, an understanding of the tecYical requirements and limitations of this tecYology is essential in order to develop a viable creative strategy. To this end, a semi-systematic review of the literature was carried out for the purpose of gathering information on possible strategies for enhancing QR codes without compromising their functionality, and to provide guidelines for manually customising these codes in a way that is effective. The aim of this paper is to reveal the amount of research that has focused on the relationship between the aesthetic characteristics of QR codes and their advertising effectiveness. The main findings include a scarcity of scientific analysis regarding this issue, yet multiple opportunities for the artistic modification of QR codes due to recent advances in generative artificial intelligence.

Keywords:

QR code; aesthetics; advertising effectiveness; mobile marketing; generative artificial intelligence.

Resumen:

Los códigos QR se presentan en ocasiones como protagonistas de estrategias de marketing digital que buscan atraer la atención de los consumidores mediante la transformación de su anodino aspecto de cuadros blancos y negros en atractivos diseños. Sin embargo, los cambios en su apariencia pueden provocar fallos en el escaneo, por lo que conocer los requisitos y limitaciones técnicas de esta tecnología es fundamental para poder plantear una estrategia creativa viable. En este trabajo se realiza una revisión semi-sistemática de la literatura con el objeto de recopilar información sobre las posibles estrategias para afrontar su embellecimiento sin poner en riesgo su funcionalidad y extraer unas directrices que sirvan de guía para su personalización manual efectiva. Así mismo, se busca conocer hasta qué punto se ha estudiado la relación entre las características estéticas del QR y su eficacia publicitaria. Como principal hallazgo, se pone de manifiesto la ausencia de estudios científicos que analicen esta cuestión y se revelan las múltiples oportunidades que surgen a raíz de los recientes desarrollos que utilizan inteligencia artificial generativa para la manipulación artística del código.

Palabras clave:

Código QR; estética; eficacia publicitaria; marketing móvil; inteligencia artificial generativa.

1. Introduction

Quick Response codes (QR) have become a regular feature of everyday life for consumers and users all over the world. The spread of this tecYology has come as a surprise even to its creator, Masahiro Hara, as his invention was originally designed to optimise inventory control in the automotive industry (DENSO, n.d.-a; Fine and Clark, 2015), yet QR codes started to be used

from 2020 onward to keep track of restaurant customers, provide access to menus, and make contactless payments. Moreover, this technology has even become commonly used for issuing health certificates (McCurry, 2020).

The transition from using these codes for manufacturing to the fields of advertising and marketing took place long before the COVID-19 pandemic. However, the need to avoid physical contact boosted its use (Pratas and Oliveira, 2023; Tsai and Peng, 2023), and it spread to many users who were previously unaware of the technology, or simply ignored it.

Based on current statistics (eMarketer, 2020), the use of QR codes seems to be on the rise three decades after its invention. A survey of advertising professionals around the world shows that these codes can play an important role in marketing strategies (Alfi, 2022). Approximately 99% of the respondents feel that advertisers who want to successfully target Generation Z should use QR codes, and 98% see potential for their use in outdoor digital marketing campaigns. Moreover, 92% of the respondents agree that greater use of these codes in digital outdoor advertising provides brands and marketers with useful data to design personalised and engaging content for consumers.

In addition to outdoor advertising, small QR codes are frequently found in many print advertisements as a link between the physical world and online content (Pena-Pena, et al., 2022; Yang et al., 2021). These codes are often the key players in the communicative process, either because they dominate the layout, or because the ultimate aim of the advertisement itself is to induce the consumer to scan the code (Ávila Muñoz and Bonales Daimiel, 2023).

Considering that one of the main objectives of any advertising strategy is to attract the attention of the target audience, when a QR is used as an advertising lure it should stimulate curiosity. However, the bland appearance of the black and white matrix does not seem to have any appeal. Initially designed for fast data reading comprehensible only to a machine, their appearance has no meaning for humans, which might limit the interest of potential consumers (Ma et al., 2023).

Bringing visual qualities to the basic two-colour grid can be a way to spark curiosity, trigger sensory responses to advertisements, and even affect user and consumer behaviour by influencing the intention to scan (W.-E. Ho et al., 2022; Liu et al., 2022; Vorobchuk and Skliarenko, 2022). One interesting example of a QR being used as the main focus of an advert is in the 2011 SEAT Ibiza campaign (Figure 1), in which the advertisement revolves around a code made up of road signs and graphics representing small stretches of road, among other features (Chen, 2011). Another example appeared on the December 2020 cover of AdNews, which featured a QR code in the form of a graphic collage that symbolised everything that happened in the pandemic year (Murphy, 2020). The advert used in the Feel it For Yourself campaign focussed on a set of codes that consisted only of words (Ads of the World, n. d.). In these three examples, the QR code was modified manually and creatively, making the codes highly attractive.

Figure 1: QR codes in the SEAT advertising campaign



Source: Chen (2011)

The motivation to carry out this research emerged from the problems encountered when trying to define a creative strategy for a musical release. The aim was to spark the interest of passers-by through a graphic display that would create a link between the look of the QR code and the title of the song to which it would give access. Figure 2 shows the first sketch to develop the idea, which was discarded soon after, as it was unfeasible due to issues inherent to the technology itself. This situation highlights the importance of knowing the technical limitations of each resource in order to propose a suitable creative strategy.

Figure 2. The sketch of a discarded QR code considered technically unfeasible



Source: prepared by the authors

The problem described above is related to the object of study in this paper, which is advertising aesthetics. This field of both theory and application deals with the artistic and sensory qualities in advertising, as defined by Dagalp and Södergren (2023), who point out that this area of research is worthy of further study. This argument is associated with the main objective of the present article, which is to gather the existing information on the possibility of aesthetically modifying QR codes, as well as its

implication for the field of advertising. The issue is to discover how to design a QR code that goes beyond simply identifying the code as something to be scanned, but which also arouses curiosity and interest by introducing visual features that invite users to access the target information.

From this general objective, four specific objectives have been established as follows: The first is to understand how QR codes work, as well as the technical requirements that limit and influence the potential for modifying their visual design; The second specific objective is to reveal the different possible strategies for customisation and embellishment of the codes; The third SO is to discover the extent of research related to whether there is a connection between the aesthetics of QR codes and their advertising effectiveness; and the fourth SO is clearly focussed on the transfer of scientific knowledge to professional practice and teaching, the aim of which is to establish a set of guidelines that will enable the manual customisation of QR codes to be carried out effectively.

2. Methodology

To achieve the objectives described above, the authors carried out a literature review as a research method to compile and synthesise previous studies. This can be useful in developing guidelines for practical applications (Snyder, 2019), as well as providing an overview of areas where research is disparate and interdisciplinary (Wong et al., 2013). In the present study, which focusses on the aesthetic side of a technological resource used in advertising campaigns, useful information for the designer or creative director can be found scattered among various research studies pertaining to the fields of engineering, social science, and the arts. For this reason, a semi-systematic or narrative approach is an appropriate methodological option due to its suitability for elucidating heterogeneous thematic areas (Snyder, 2019; Wong et al., 2013).

Following the steps outlined by Snyder (2019), a strategy for locating the relevant literature has been developed, starting with the choice of search terms and databases to be consulted.

2.1. Criteria for the corpus selection

An initial enquiry was made in the Web Of Science database (WoS), using “QR” as the search term in the keyword field, while at the same time the term “aesthetic” was placed in the title. This search yielded only 12 results. By examining the bibliography cited in the most relevant articles, other terms used to refer to aesthetics were observed, such as “stylised”, “artistic”, and references to images embedded in the codes themselves. From this analysis, a list of similar terms was established, including “design”, “style”, “art”, “embellishment” and “customisation”, along with variants such as “beauty” and “beautification”. In this way, a wide spectrum of terms related to aesthetic features was obtained, both in Spanish and English. Boolean operators were used to locate articles that contained any of the search terms in the title. Moreover, advertising terms such as “marketing”, “advertising”, “advert” and “brand” were added to the list, as well as “artificial intelligence” and its acronym, anticipating the possibility that image-generative artificial intelligence is being used to create stylised codes.

The same search strategy was used in three databases in total: WoS, Scopus, and the ACM Digital Library (ACM)¹. In the latter, the catalogue entitled, “The ACM Guide to Computing Literature”, was accessed due to the fact that it contains a larger number of references and includes all the references in “The ACM Full-Text collection”.

Next, a second search was carried out. On this occasion, the aim was to find articles in the field of advertising that might have contained information on QR aesthetics without this being the main subject of the research, which is why this term, or one of its synonyms, might not have appeared in the title. This would be the case, for example, of a study regarding the factors that affect the intention to scan, using the aesthetic design of the QR code as one of the possible variables. Thus, a search for references was conducted in the three databases that met the following criteria: occurrence of the term “QR” among the keywords and in the title, in addition to terms such as “advertising”, “marketing”, and “advert”, also in the title, once again taking into account the English and Spanish variants. The result of this second search yielded 55 results: 20 in WoS; 34 in Scopus; and one in ACM.

Table 1. Literature search process

	WoS	Scopus	ACM
SEARCH 1: “QR” in keywords AND “aesthetics” (or variants) OR terms related to advertising and marketing OR artificial intelligence in the title.	217	320	53
SEARCH 2: “QR” in keywords AND “QR” AND advertising and marketing terms in the title.	20	34	1

Source: prepared by the authors

The total of the two searches yielded 645 records, many of which were predictably repeated, due to the high number of communication journals indexed in both WoS and Scopus (Codina et al. 2020), or because they appeared in both searches. With the help of Zotero, which is a reference management software, duplicates were eliminated, reducing the selection to 430 records.

Among the results of the first search, we find a good number of studies in the field of engineering in which the term “design” appears, but not as a reference to the visual design of QR codes. These works are focussed on the design and implementation of logistics, warehousing, and access control systems, to offer a few examples. To select the most relevant articles within this group, texts published between 2020 and 2023, inclusive, were selected first, and all the articles that did not contain terms in the title directly related to aesthetics, QR embellishment, customisation, or the use of embedded images, were eliminated from the articles published before those dates.

1 As an example, the following search formula was used in Scopus: “(KEY [qr OR “qr-code” OR “qr code”] AND TITLE [design OR aesthetic OR style OR art OR beauty OR beautification OR personalisation OR custom OR artistic OR embed OR “AI” OR “artificial intelligence” OR advertising OR advertisement OR brand OR marketing OR advertising OR advertisement OR brand OR brand]).

Among the findings of the second search, there are also numerous articles that deal exclusively with the functional variant of the use of QR codes, which are of no interest to the present study, as this paper focusses on the aesthetic potential of the codes. This is the case, for example, in marketing studies that analyse the acceptance of payment systems that use QR codes.

After this selection process, the sample was reduced to 217 articles, which were analysed in even greater depth by reviewing the title and abstract in order to continue with the process of discarding texts. A considerable number of references that addressed the development of security systems based on visual cryptography using images embedded in a QR code, or those that focussed on creating image protection and security algorithms, were also discarded. Finally, 68 potentially relevant articles were selected, which required further analysis to assess whether or not their content was relevant to the objectives of this study. Of these 68 articles, 39 focus on the research field of engineering and computer science, and 28 address advertising and marketing. Finally, it bears mentioning the work of Vorobchuk and Skliarenko (2022), who have approached the study of QR codes from the field of visual arts, analysing how the aesthetic enhancement of the codes makes them an important factor in visual communication.

3. Results

The articles devoted to studying the use of QR codes in marketing and advertising focus on consumer motivation and attitudes toward using these codes in different media, and on packaging as well, by analysing their impact on the intention to scan and/or purchase. Pratas and Oliveira (2023) have carried out a bibliometric study and content analysis aimed at pinpointing the main research topics related to the use of QR codes in marketing and their evolution over time. The most common topics revolve around the following issues: the willingness to use QR codes, and the intention to purchase through the codes in the retail industry, communication and collaborative supply chains; risk and privacy issues with QR codes and customer loyalty programmes; mobile payments with QR codes; and other specific aspects related to the industry. The issue of QR aesthetics was not addressed in their study.

The lack of research on the visual design of QR codes for advertising and marketing has been confirmed by an in-depth examination of the 28 texts selected for this study. The interest of researchers is focussed mainly on the following issues: whether or not consumers scan the QR codes printed on packaging to access product information (Kim and Woo, 2016; Li and Messer, 2019; Tallapragada and Hallman, 2018; Yang et al., 2022); consumer behaviour and QR effectiveness based on customer lifestyles (Kang and Choi, 2019) or backgrounds (Demir et al., 2015; Meydano lu et al., 2018; Meydano lu et al., 2015; Santos, 2015); the impact on the intention to purchase and customer satisfaction based on the perceived flow (Hossain et al., 2018); its influence on consumer choice among product assortments in online shops (Hattula et al., 2015); its use as a communication tool in the context of corporate marketing activities (Aydin et al., 2019); as a strategy in political marketing (Ballesteros-López et al., 2023); and to enhance the sustainable gastronomic experience (Albuquerque et al., 2020). Some articles have been found that evaluate the following: publication of location-based advertisements using QR codes (Virulkar and Bhute, 2016); the feasibility of advertising business products (Silva Ordonez et al., 2016); the potential use of the codes in various media or business domains (Berndt-Morris and Chrenka, 2014; Kim and Yu, 2013); the development of digital marketing support applications based on QR codes (Park et al., 2012); and QR label printing systems for department stores that allow visually

impaired customers to identify purchased products (Haraikawa et al., 2013). Less recent articles have analysed QR codes as the latest phenomenon in mobile marketing (Patel and Cata, 2013; Sang Ryu and Murdock, 2013), and general factors that might affect its use (Ozkaya et al., 2015). All the studies listed above were based on QR codes that did not have any changes to their visual design, and hardly any references have been found that include the potential for making aesthetic changes to the codes.

Regarding the publications analysed that are related to the fields of engineering and computer science, the research focusses mainly on the development of algorithms and programmes for creating aesthetic QR codes. These texts are highly technical and aimed at developing different methods for generating codes or modifying their appearance in an automated way. Some of the most recent studies use AI-based methods, such as Deep Learning, to optimise processes (Haisheng et al., 2021; Pena-Pena, et al., 2022; Tsai and Peng, 2023; Yang et al., 2021).

In recent years, increased attention has been paid to the aesthetic embellishment of QR codes (W.-E. Ho et al., 2022). The number of articles found indicates an active interest among the research community, especially if one considers that the texts focussing on visual cryptography, in which similar methods are developed, have been left out of this study.

It is common to find arguments that allude to the potential usefulness of QR codes for social events, advertising in different media, and as an integral part of packaging, yet it has been observed that the codes currently being used on the market still have the standard black and white checkered appearance (Bao et al., 2017; W.-E. Ho et al., 2022; Y.-H. Ho et al., 2022; Huang et al., 2020; Tsai et al., 2023; Tsai and Peng, 2023).

Ma et al. (2023) point out that the binary aspect of these codes may limit the interest of potential consumers, and that many ideas have been proposed to solve this problem, with the embedding of images being the most promising approach. These authors point out that even the most advanced designs still have room for improvement, as many of today's systems still require maintaining some of the structural components of the QR code, such as position detection patterns (see Figure 3). In their proposal, they have developed a scheme that allows codes to be created without these patterns.

As the aim of this article is not to determine which algorithm for automated code generation is more or less efficient or robust when scanning, this line of thought will not be pursued further. However, the texts reviewed provide valuable information on the problems associated with the visual modification of QR codes and possible customisation strategies. The most relevant findings from the two searches are presented below, organised according to the four specific objectives.

3.1. Structure and operation of a QR code

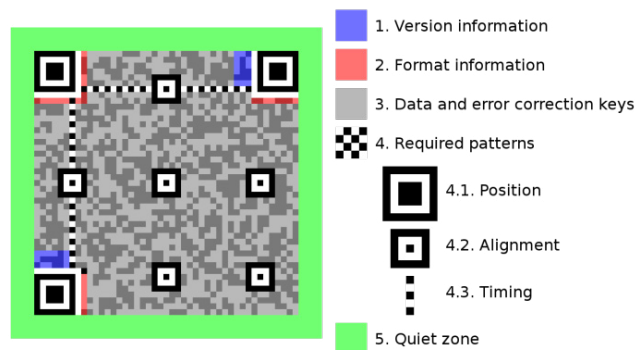
The aim of this section is to offer a synthesis to the designer or creative director that will provide the basic information needed to understand the characteristics and limitations of this technology, without discussing technically complex issues. For those who would like more complete information regarding technical specifications, the following sources can be consulted: the official website known as qrcode.com (DENSO, n.d.-b); the ISO standards; and the training manual of the *Asociación de Autores Científico-Técnicos y Académicos* [association of scientific-technical and academic authors] (Luque Ordóñez, 2012).

Quick Response codes are a matrix of black and white squares arranged in a two-dimensional way (horizontally and vertically), which store information in a binary language, in which white equals 1 and black equals 0, representing 1 bit of information (Tsai and Peng, 2023). The apparently random distribution of the modules actually involves a specific coding of letters and

numbers (Pratas and Oliveira, 2023). There are different models and versions, which may contain more or less information, depending on their characteristics and number of modules. Version 1 consists of a matrix of 21x21 modules. Each version incorporates 4 modules on each side, reaching 177x177 in version 40 (Tsai et al., 2023).

It is important to note that not all modules contain coded information. Some areas contain information that is essential for scanning and decoding, while others contain redundant and therefore unnecessary information. This feature allows codes to be readable in the event of being torn or damaged. Moreover, this is essential for inventory systems in the manufacturing industry, for which they were originally intended (Tsai and Peng, 2023). Thanks to this feature, the appearance of the code can be partially modified without jeopardising its readability (Li et al., 2016). The area that can tolerate damage varies depending on the QR version, but it can reach up to 30% of the codewords, which are the units that construct the QR data area in groups of 8 bits of information.

Figure 3. Structural elements of a QR Code

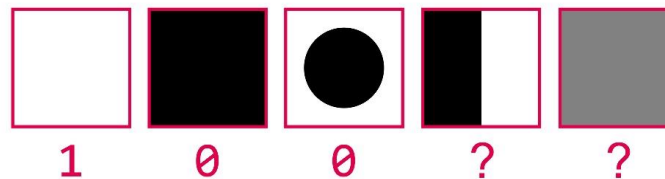


Source: Bobmath (2013)

The basic structure of a QR code consists of a number of areas intended to contain version information, the format, and various function patterns which, to offer an example, allow the scanner to interpret the orientation of the code (Figure 3). In addition, there is a frame surrounding the matrix called the quiet zone, which must be preserved in order to avoid problems in scanning (W.-E. Ho et al., 2022; Tsai et al., 2023; Tsai and Peng, 2023). According to Bao et al. (2017), it is recommended to avoid the graphical information area of the function and the QR code version when inserting an icon in the matrix, and to be sure not to occupy an area of more than 30% of the coding space.

Changes in the appearance of QR codes can lead to scanning failures. It is therefore a major challenge to maintain the robustness of the codes if they are modified using colours and textures (Su et al., 2021). It also bears mentioning that codes must be resistant to variations in lighting (Xu et al., 2021). For example, in low light conditions, white modules may appear grey. A scanner will not be able to assign a value 0 or 1 to a grey module at 50% brightness. Moreover, if the module area is not clearly covered by a certain colour, the scanner will not be able to determine which value to assign (Figure 4).

Figure 4. Depiction of the binary interpretation of the module during the scanning process as a function of contrast level and occupied area



Source: prepared by the authors

The decision of which value to assign to a data module is a critical issue in determining decoding capability and, at the same time, is the factor that creates the most noise in displaying an image blended with the matrix. W.-E. Ho et al. (2022) propose an algorithm that gives more weight to pixels that are closer to the central region of each module, thereby achieving robust scanning and improving the visibility of the embedded image in the code.

In the print media, information contained in the code might be eroded due to the quality of the printing process itself, or as a result of the print size, which can affect the recognition and decoding process as well (Y.-H. Ho et al., 2022; Xu et al., 2021). In a study developed by Y.-H. Ho et al. (2022), the authors printed the codes to a size of 2.1 centimetres and 600 dots per inch, obtaining satisfactory results.

3.2. Customisation and embellishment strategies

Vorobchuk and Skliarenko (2022) have studied the evolutionary stages of barcodes and QR codes. They consider the early 21st century to be the period in which artistic attributes started to appear in QR codes to improve their appearance, giving rise to an artistic language. The foundational elements of code design are image, structure, and context. The combination of these elements, which adhered to associative, variable and adaptive principles, provided the foundation for creating harmonious works of art that attracted the attention of consumers by generating interest in the encoded communicative content. In order to illustrate how improving the aesthetic appearance of codes can make them an important feature of visual communication, these authors have provided the following examples: turning a basic QR code into a symbol that resembles a gift package by adding a ribbon and label to the matrix; modelling a three-dimensional QR code by joining together physical objects; constructing a code by using the shadows generated from sunlight at a certain time of the day; making a code perceptible when observing a set of structures from a certain point of view; and giving visibility to a code by filling a glass with a dark liquid in which the white modules have been printed, which are difficult to see when the glass is empty.

Xu et al. (2019) have identified four possible strategies for modifying the visual style of QR codes. Firstly, there is the embedded approach, which uses the error-correction capabilities of QR codes to insert small icons into the code matrix. The second strategy is to modify the shape and colour of the modules. Thirdly, there is the manual approach, in which the visual configuration of the code is not generated automatically by an algorithm, but by the creative work of an artist or designer. Fourthly, there is the blended approach, which merges a large image with the QR matrix. The authors consider the latter to be the most promising

strategy, which is the approach taken by the most recent studies. Figure 5 shows examples of codes generated on the qrbtf.com website by automated systems. From left to right: (1) basic code; (2) embedded type; (3) change of colour; (4) change of module shape; (5) change of colour and module shape; (6) image blended with the matrix.

Figure 5. Examples of QR codes generated by algorithms



Source: codes generated by the authors using the qrbtf.com website; photo by Alba Robles

Among the algorithm-based customisation systems, in addition to embedding icons and changing the colour or shape of modules, Xu et al. (2021) describe another procedure based on the adjustment of codewords, yet they point out that the results obtained from this method have poor and often inconsistent visual quality. This procedure generates a matrix configuration in which a graphic element can be identified with an appearance that maintains the two-colour, quadrangular aspect of the modules. The same result can be achieved by reassigning the black and white colours of the matrix points, yet this method is limited by the error correction rate, whereas the codeword adjustment shows images without inherent errors. Figure 6 shows two examples generated by this method, showing the images of both a bell and a face.

Figure 6. Example of codes created by adjusting codewords



Source: examples borrowed from Cox (2012)

On the social network Reddit (5 June 2023), a developer known as *nhciao* posted some artistic QR codes created by using ControlNet, which is an extension of the Stable Diffusion generative artificial intelligence model (nhciao, 2023a). His creations integrated the code modules into complex illustrations (Figure 7).

Figure 7. Selection of codes generated by ControlNet



Source: screenshot of a Reddit post by nhciao (2023a)

Three weeks later he published more samples, some of which can only be scanned using the WeChat application, in which he successfully hides the positioning patterns (nhciao, 2023b). The results have been so attractive and visually complex that it is sometimes difficult to see the QR code in the image (see Figure 8).

Figure 8. Selection of codes with hidden position patterns



Source: screenshot of a Reddit post by nhciao (2023b)

Almost immediately, social media and various online publications started to echo the novelty. One post made by a user on LinkedIn (Beliūnas, 2023) shows several examples of QR codes generated by nhciao, which received tens of thousands of reactions and thousands of comments within a few days. Interesting debates have emerged regarding the potential of this combination of art and technology, which some believe could change the future of marketing. Some observers question the usefulness of these artistic codes and even cast doubt on the utility of QR codes in general. Others express surprise at reading these comments and point to the prevalence of QR codes in all parts of Asia, especially in China, noting that artistic codes could be used to enhance branding by incorporating features of corporate identity into the codes, or by integrating QR codes into advertisements in creative and innovative ways, rather than simply placing the classic square design at the bottom of an advert. Another issue is that simply because something is ubiquitous does not imply that it is useful or beneficial, and the importance of validating the effectiveness of these highly stylised codes has been pointed out as well. Finally, another key point is the problem posed by these artistic codes: How can people be made aware that these QR codes are capable of being scanned?

On 13 July, the above-mentioned creator, *nhciao*, announced on his Discord channel the first version of QRBTf.AI, an application for the creation of generative QR codes accessible from the *qrbtf.com* website. Along the same lines, QR Diffusion was also developing a model whose beta version was announced in the same month of July 2023, and on their website it is possible to test the pre-alpha version (*QR Diffusion*, n.d.) and to start experimenting with this technology through tutorials that explain the process step by step.

3.3. *Aesthetics and advertising effectiveness*

Discussions regarding the importance of attracting the user's attention and awakening the consumer's curiosity through the aesthetic design of QR codes are common in articles found in the field of engineering. However, no reference has been found that provides empirical data on the actual effectiveness of this variable. In this regard, the work of W.-E. Ho et al. (2022) stands out, as these authors conducted an online survey with 40 participants to assess their perception of the visual attractiveness of the codes generated with their algorithm. Although they mention the importance of the visual appeal of adverts in maximising their persuasive effect, the study actually focusses on comparing the results obtained with their system and other generators. However, due to the number of participants and the approach of the study, the research findings were not deemed to be representative of the general population.

The studies in the selected sample that refer to aesthetic issues do not refer to the appearance of the QR code itself, but rather to the visual characteristics of the advertisement in which the code is inserted. Covic et al. (2016) pose the challenge of making QR codes that attract people's attention. These authors question whether it might be enough to simply display the code without any additional information, or whether the code will be more effective if accompanied by a slogan, company logo, or both, yet the same authors have not examined the variable of embedding or blending these elements into the QR matrix. Instead, they have focussed on the composition of the advertisement using a basic code alongside the logo or slogan. According to Trivedi et al. (2020), traditional codes can be replaced by codes printed in multiple colours, or those that include brand names or logos, yet this factor has not been taken into account in their study on the effectiveness of pull-based print advertising using QR codes. Kjeldsen et al. (2023) have analysed the way in which customisation of the information provided by a QR code can affect the buying process, an example of which is an offer of personalised prices for a technological product, yet these authors have not considered the way in which customisation of the visual design of the code can affect the purchasing process. Okazaki et al. (2019) have focussed on how curiosity, the complexity of the visual design of the advertisement, and the perception of a link between the QR code and the advertised brand jointly affect the consumers' intention to scan the code. The designs employed in their experimental study use only basic QR codes, so factors such as product image integration or the inclusion of graphic brand features within the QR code itself have not been analysed.

3.4. *Guidelines for manual customisation*

Until automated systems were developed, most aesthetic codes were designed manually by artists who modified the modules by changing their colours, softening the edges, or adding graphic aspects. The final step in the process was to confirm that the code could be recognised by scanners (Li et al., 2016). Manual changes to the appearance of QR codes is costly and difficult to

achieve due to being labour and resource intensive, and there is the added problem of not being able to ensure decoding (Xu et al., 2021).

There are currently many online applications that enable the generation of a somewhat stylised code. However, despite the significant developments reported in the literature with regard to automated methods, in some cases such as those presented in the introduction, or others described by Vorobchuk and Skliarenko (2022), they could be developed using algorithm-based systems including generative artificial intelligence, yet this would involve a more tedious developmental process. To obtain specific results in line with a given creative idea, it could be more efficient for the designer to directly manipulate the matrix modules in the code. However, in doing so they must take into account the characteristics and limitations of the technology. In response to the fourth objective of this paper, the following are recommendations drawn from the information found in the literature review for the purpose of embellishing and styling a basic code:

1. Pay attention to the number of modules contained in the initial QR code when generating a new design. For example, if the QR code links to a website, the number of characters in the address will influence the number of bits of information needed and, consequently, the number of modules necessary to encode the data, so it may be advisable to use a URL shortener.
2. When modifying colours, ensure that there is black and white equivalence with the new colour palette, while keeping a good level of contrast.
3. Cover most of the square area of each module, especially regarding its central area.
4. In cases of removing or hiding modules, do not exceed the error correction rate, which should be a maximum of 30% of the data area, yet this rate could be lower depending on the QR version used.
5. Avoid altering the function patterns and areas intended to house the version and format information of the QR code.
6. Preserve the quiet zone around the QR code.
7. Consider the size at which the code will be displayed, both on physical and digital media, taking into account the distance at which the user will be positioned, so that they can scan the code comfortably. The size of the code will also depend on the number of modules and the visual complexity of the modification carried out.
8. In the case of printed codes, use the best possible print quality and avoid materials that may change the appearance of the colour or generate visual noise, such as reflective, recycled, or textured paper.
9. Keep in mind the ambient lighting conditions in which the code will be displayed. For example, if the code is displayed in a dimly lit space, a higher level of colour contrast or a larger print size may be necessary.
10. Check that the final result is recognisable by scanning it with various devices in its context.

Many factors beyond the control of the designer can affect the readability of a QR code, such as lighting conditions, the quality of the consumer's phone camera used for the scanning, and the potential for QR deterioration due to exposure to adverse weather conditions. As such, these general recommendations are intended to serve as a basic guide for decision-making during the creative process, which cannot be taken as a guarantee of success for the creation of a robust QR code for scanning.

4. Conclusions

This research has emerged from a real case study in which the creative strategy proposed was unfeasible, as it was not compatible with the attributes and functioning of Quick Response Codes. Based on a literature review, an exploratory study has been carried out, which has allowed the authors to address several of the specific objectives set forth, as well as to reveal the shortcomings of the study, and to identify opportunities for future lines of research.

Regarding the first objective, the technical information required for understanding the structure of a QR code, as well as the factors that limit its aesthetic modification, have been compiled.

Concerning the second objective, the authors have identified the two most common ways of customising the visual design of a QR code: by using algorithms; or by manually modifying the code. Regarding the former, various systems have been developed over the years in order to achieve greater attractiveness and more freedom in the use of aesthetics, while maintaining robust scanning results. Recent developments using generative artificial intelligence have made it possible to attain highly stylistic results in which the distinctive features of the QR code are difficult for the human eye to perceive, yet not for the scanner. While new developments in highly stylized AI-generated codes might open up new directions in the field of advertising, there is no guarantee that this will be the case. Certain issues, such as identifying which visual features are essential for allowing users and consumers to recognise whether a certain design can be scanned or not, are fundamental in defining strategies for creating artistic QR codes.

Regarding the third objective, it was not possible to determine whether there is a relationship between the aesthetic features of a QR and its advertising effectiveness, due to a lack of empirical studies in this area in the literature reviewed. One of the contributions of the present study is the fact that it highlights the research opportunities that have emerged from the shortcomings revealed. There is a clear need to provide empirical support to engineering researchers who are trying to achieve improved algorithms by referring to the potential efficacy of using embellished codes for advertising appeal.

In response to the fourth and final objective, a set of recommendations has been provided to help designers and creative professionals accept the challenge of manual customisation of QR codes when it is not possible to achieve the desired aesthetic design through automated systems. This will allow them to develop a strategy that will be as effective as possible given the variables over which they have control.

Despite having carried out a methodical review of the literature, the use of only three reference databases is one limitation to this study. The reason is, texts published in many other scientific databases, as well as everything that can be found in the so-called *grey literature*, the latter of which includes references that provide relevant data yet are outside the conventional channels of scientific distribution, have been left out of this study. Nevertheless, due to the scarcity of information regarding the creation of artistic QR codes using generative artificial intelligence models revealed in the literature review of this study, the need to broaden the origin of sources when looking for research opportunities has been put in the spotlight.

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6. Specific contributions of each author

	Name and surname
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Methodology	Raquel Ávila-Muñoz
Data collection and analysis	Raquel Ávila-Muñoz
Discussion and conclusions	Raquel Ávila-Muñoz, Gema Bonaes-Daimiel, and Fernando Suárez-Carballo
Drafting, formatting, version review and approval	Raquel Ávila-Muñoz, Gema Bonaes-Daimiel, and Fernando Suárez-Carballo

7. Conflict of interest

The authors declare that there is no conflict of interest contained in this article.

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