Using Embossed QR Codes on Product Packaging for People with Visual Impairments

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Abstract

Vision impairment severely impacts quality of life among adult populations. People with vision impairment often have to deal with a number of problems in their every-day life. One of them is related with their shopping and after sales experience. They need assistive tools so that they can get information about the products they shop and store in their home. QR codes is a well-known technology that contains a link and directs mobile users to a specified website. This website can include various and multimodal information related to a product that can easily be received through audio from peopled with visual impairments. In this paper we propose a solution for people with visual impairments in order to improve the way they shop. From the company's side, QR code labels are printed and placed on the product's packaging while on the same time a mobile application that supports QR code reading has been implemented. The users, scanning the QR code of a product using the mobile application, can seamlessly be redirected to the product-related audio information. The proposed approach and the implemented mobile application were tested by a group of people with vision impairment in order to assess its usability, satisfaction and intention to use. The evaluation results revealed that people with vision impairment find the provided mobile application useful and easy to use, while they are totally satisfied with the proposed approach, and they intend to use it in the future.

Keywords: vision impairment; QR code; products; shopping;

JEL Classification: M51; M37; I12;

DOI: http://doi.org/10.24818/ejis.2022.25

1. Introduction

Vision impairment is a term that experts use to describe any kind of vision loss, whether it's someone who cannot see at all or someone who has partial vision loss. According to the World Health Organization (WHO, 2021), globally there are at least 2.2 billion people that have a near or distance vision impairment. Furthermore, vision impairment has a significant impact on the lives of those who experience, their closed ones and in the society they live. It has a negative impact on people's lives and affects their quality of life since they feel less independent (Welp *et al.*, 2016). Some aspects of their life that are affected are everyday activities like reading, socializing, driving, medication management and shopping. In order

Received: 26 August 2022; Revised: 15 September 2022; Accepted: 30 November 2022

to do these tasks, people with vision impairments often rely on their closed ones, friends and family.

Quick Response (QR) codes have been used severely for marketing purposes. Nowadays QR codes are printed on many products, providing additional information about the products and the company, building direct connections with customers, and collecting data. Consumers can participate in contests and giveaways or provide feedback by filling in questionnaires that the company creates. In most cases, QR codes contain a link that directs customers to a specified website. The new trend in marketing is the use of dynamic QR codes. By scanning a dynamic QR code, consumers are directed to different campaigns, based on several variables, like location, time of day, or day of the week. It is easier for a company to have a landing page and then redirect consumers to the right location based on the company's needs. This eliminates the need to print a new QR code and add it to the product each time. A redirect page that sends users to alternate location can be easily created using a PHP script. Furthermore, when the scanning of the QR code is performed via the company's mobile application, further information can be retrieved such as the location of the user, profile and recent purchases. All this information can be passed to the landing page and then the user can be redirected to a more personalized page based on the data passed.

In this paper we propose a solution for people with visual impairments in order to improve the way they shop. From the company's side, QR code labels are printed and placed on the product's packaging. Labels have embossed edges so that can be easily located by touch. Once located, consumers can open the company's mobile application and scan the QR code. Then, they are seamlessly redirected to the information provided by the company regarding the specific product. Finally, the information is played as an audio file from the smartphone device. The company can edit all the information that provides to the consumer and since dynamic QR codes are used in product packaging, there is no need to re-print new labels on the products.

Our solution not only helps visually impaired customers with their in-store shopping, but it can also assist them identifying the products in home and provide useful information about them. Although some stores are capable for providing information to visually impaired people using dedicated personnel, this help stops when customers leave the store. Visually impaired people would like to know what a product is before they open it (Haraikawa *et al.*, 2013). They also have the need to be informed about the product that they see in the supermarket, but they also need to have access to this information after purchasing the product and putting it on a shelf at home. The proposed approach was tested by a group of 12 people with vision impairments in order to assess its usability and its effectiveness.

The remainder of this paper is organized as follows: Section 2 presents the related work regarding the use of QR codes for marketing purposes for people with visual impairments. An overview of the architecture of the proposed system will be depicted in Section 3. Section 4 presents the adopted research methodology and the evaluation findings by people with visual impairments, while the discussion and conclusion of this study are listed in Section 5.

2. Related work

Ozkaya *et al.* (2015) searched for the factors that contributed to the use of QR codes among consumer populations and concluded, after a survey with 174 university students, that there

are two distinct types of users: practical users and experiential users. Practical users utilize QR codes for getting more information about the product, while experiential users are more interested in socializing and accessing entertainment media. Practical users are closer to purchase and as the study suggests, companies should provide this option through the QR code.

An early attempt on using QR codes for blinds and visually impaired people was made by Al-Khalifa (2008). The author proposed the idea of users scanning a QR code and then redirect them to a URL where the description of the product was included. A server containing the audio file of the description was sent to the mobile device and was played. A text to speech engine was also used in the mobile phone, in case there was no pre-recorded audio file. The proposed system was not tested so there are no results regarding its perceived usability by the users.

A wayfinding system that helps individuals with cognitive impairments with navigating indoors or on the road using QR codes was proposed by Chang *et al.* (2007). Ten cognitively impaired participants used PDAs to follow specific routes and only 4% of the participants deviated from the set routes. The drawback of the system is that is based on PDAs and not on smart phones.

A system consisting of a PC-based POS terminal, a barcode scanner and a label printer was proposed by Haraikawa *et al.* (2013). Customers would need to always carry the barcode scanner in order to scan the products. This is not very practical due to the cost of these devices. Since most users are equipped with smartphones and carry them with them the whole time, it would be better to have software that runs on mobile devices.

López-de-Ipiña *et al.* (2011) proposed the BlindShopping platform. The platform enables accessible shopping for visually impaired people using mobile technologies. The proposed platform consists of a navigation system in a supermarket that guides a blind person to the desired location. Products are put in a specific order on the shelves and the user after successfully locating the product, scans the QR code printed on the item, using a mobile phone. After successful recognition, the phone verbally provides information about the product.

Torrado *et al.* (2016) developed a system, called AssisT-In, which consists of an Android application that can scan QR codes. The purpose is to assist people with cognitive disabilities while they are navigating at home. It is mandatory that the QR codes are placed in the indoor environment at suitable places where they cannot be mistaken for other decoration/advertising QR codes. The mobile application asks the user what the desired destination is and then, after scanning a QR code, the application will guide the user from this spot to the next one, leading to the destination. The application provides an image of the next spot as seen from the current spot, to guide users. All of the 14 users with various types and degrees of cognitive impairment that participated in the evaluation of the application, successfully reached their destination spot in an unfamiliar environment.

Another system that incorporates functions for visually impaired persons using Android devices is Voice Helper developed by Liu *et al.* (2015). The system includes a message reader, a voice dialer, an OCR reader, a QR code reader and other functions. The QR code function, scans a QR code and then reads out the content of the code. Voice Helper was not tested in real life scenarios by visually impaired users, so its usefulness is yet to be determined.

QR codes were also used by Hodage *et al.* (2018) and specifically on packages of drugs. Authors created an android application that provides an easy way to scan a QR code on a

medicine and provide information to the visually impaired in order to take it according to their doctor's prescription. Voice reminders on when to take the medicine are also present in the application. The purpose of the application was to help visually impaired people to be more independent in finding and receiving their medication. This solution can also assist elder people who are not educated and usually suffer to read their medicine names on their own. Although it seems a good application, Hodage *et al.* (2018) do not provide any evaluation results from the end users.

From the above it is obvious that a) most of the applications do require specific infrastructure, other than a mobile phone, that the majority of users already have, and b) most of the papers do not provide any evaluation results and therefore we cannot conclude safely on the applications usability, usefulness and consequently to the user adoption.

This paper proposes a mobile application that allows visual impaired people, among other, to scan an embossed QR on the final product, using any mobile device (either Android or iOS) and get information about the product both in visual and audio format. In addition, it provides details from the pilot evaluation of the application.

3. Proposed System

According to the proposed approach embossed QR Code tags will be placed on the products box, and users will use their mobile phone to scan them in order to hear audio information about the products. Therefore, there is a need of a software system that will recognize QR Codes and provides the appropriate information to the user.

The proposed system is consisted by a web-based back-end authoring tool and a mobile application. The authoring tool is used by the system administrators and content creators in order to provide information about company's products. On the other hand, mobile application is used by the end users, people with visual impairments, to scan product's embossed QR code and retrieve the appropriate information.

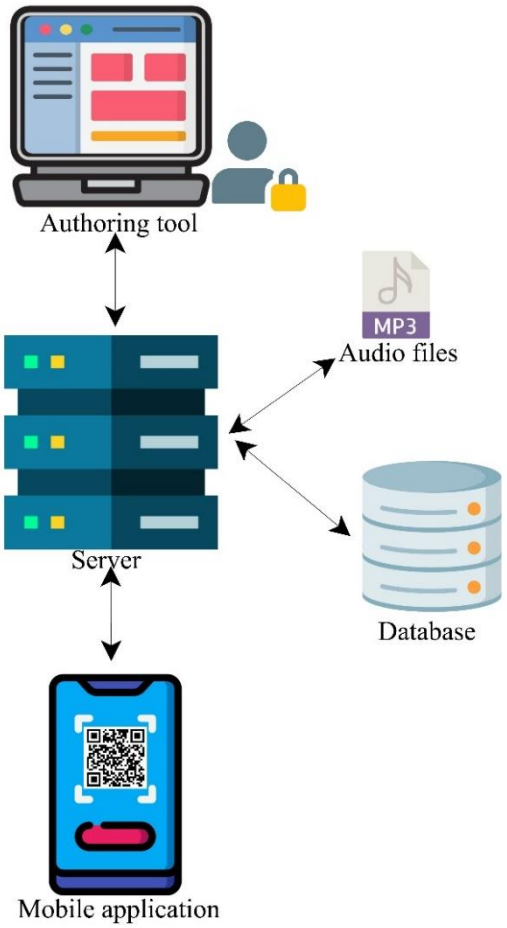
3.1 System Architecture

The proposed system follows a simple architecture. A server is used to store the necessary audio files that are retrieved from the mobile application. A database is also used to store the appropriate information about the products, nutrition info, and packaging details. An authoring tool is hosted on the server and allow administrators to add or edit the appropriate information about the products. The provided content can be either text, images, videos and audio files, however in the specific case for people with visual impairments the system provides only audio content. All the above software systems can be hosted at the same server of company's webpage so there is no need for a dedicated server for the platform.

A mobile application for Android and iOS is used by consumers to scan the products and retrieve the appropriate information. The audio file that contains all the information of each product is played in the consumer's device. Thus, the only restriction is that consumers should have a smart phone and an Internet connection to retrieve the provided information.

Data analytics is also stored in the database when a product is scanned, for marketing purposes. The system architecture is depicted in ***Figure 1***.

Figure 1. Platform architecture



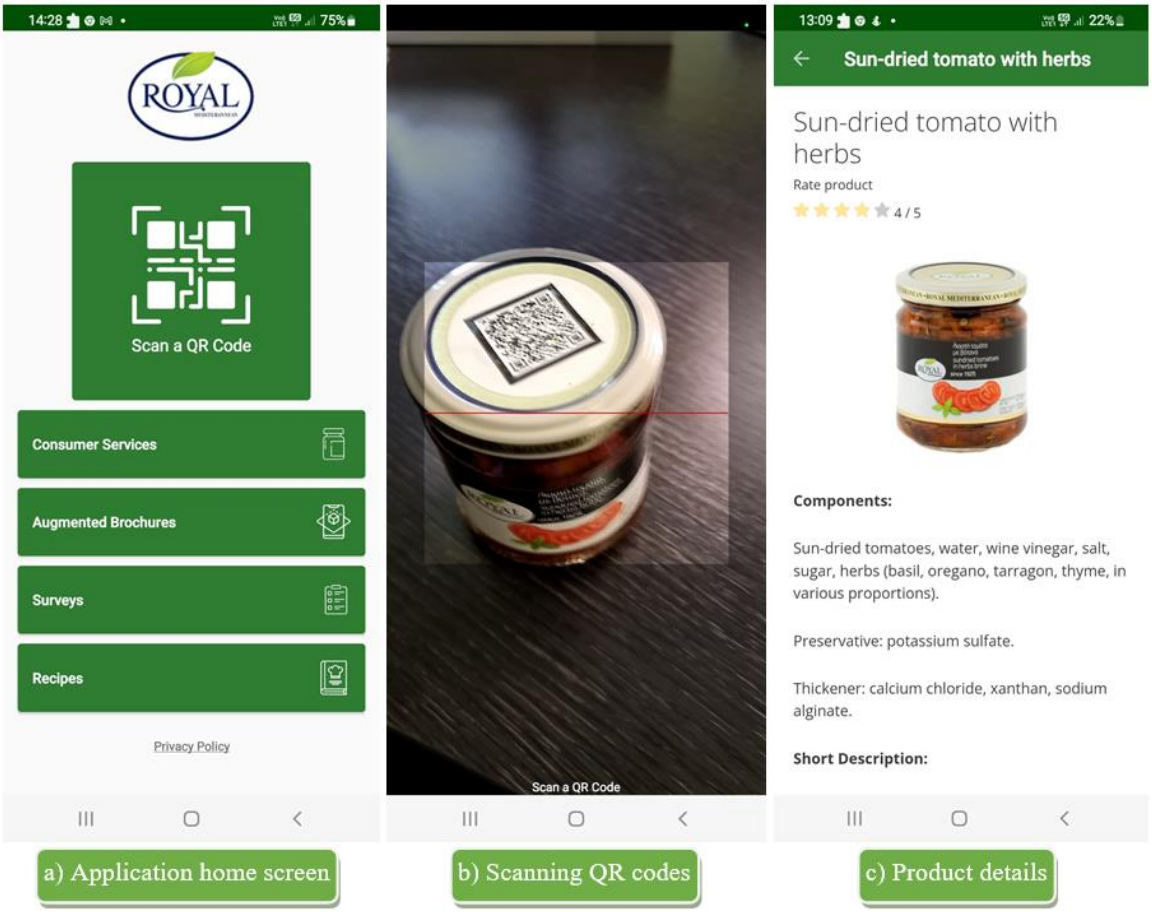
3.2 System Design

Thinking about potential users of a mobile application, especially when this application is intended for consumers use, we should also include visually impaired people. There are two categories of users with vision impairments: those with low vision and those with no vision. While both of these users fall under the category of "visually impaired," they have very different needs (Zafar, 2017). Worldwide there are more than 285 million (Theodorou and Meliones, 2020) visually impaired people and about 39 million of them are blind (Zafar, 2017). Therefore, it is important to design an application intended for consumers, in a way that help users from both categories to access the provided functionality.

The proposed system is intended for use by people with visual impairments, older people and customers that want to get some more information about the company's products. For this reason, the mobile application adopted a simple, user centered design based on Nielsen (1994) usability heuristics with the aim to enable all types of users to utilize its main functionality. Specific for visually impaired people, the proposed mobile application allows them to scan a QR code on the product and provide them with a narration about the product information. This functionality will help them during and after the buy of the product.

Figure 2a presents the home screen of the mobile application. It keeps a simple design with only five buttons. The "Scan QR Code" button is intentionally designed oversized, to allow visually impaired people to easily locate it on the screen. Once it is clicked, the mobile device camera is turned on, and the users can scan the product QR Code (***Figure 2b***). The mobile app will then provide details about the product both in audio and visual format (***Figure 2c***).

Figure 2. Application screens



3.3 System Implementation

The authoring tool is a web-based application, implemented in PHP programming language, storing the necessary information into a MySQL database. The authoring tool provides to the system administrators the appropriate tools to create and update all the provided information. The web-based application was hosted on an APACHE Server. The mobile application has been implemented both for Android and iOS devices. For Android devices Java was used as a programming language. On the other hand, Swift was used for the implementation of the iOS mobile application. All the graphic parts of the application and web authoring tool were designed and implemented using Adobe Photoshop.

4. Evaluation

4.1 Research Methodology

The main aim of the research was to assess the proposed approach and the implemented mobile application, according to Technology Acceptance Model (Davis, 1989) with focus on the visually impaired people. The research questions (RQ) were:

- RQ1. Do visually impaired people find useful the mobile application?
- RQ2. Do visually impaired people find easy to use the mobile application?
- RQ3. Are visually impaired people satisfied from the provided functionality and proposed company services?

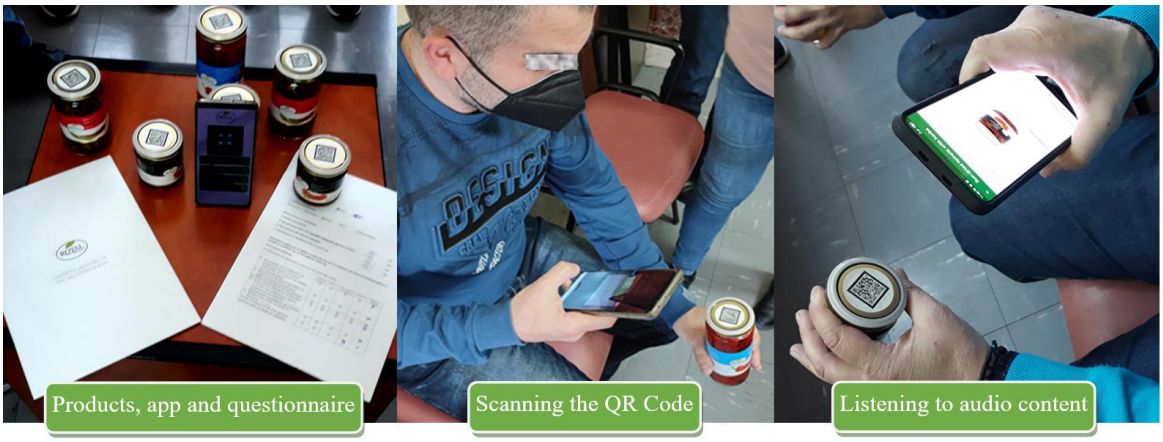
- RQ4. Do visually impaired people intent to use the mobile application?

In order to acquire the appropriate information, a seven-part questionnaire, with 28 questions, was used. The first part contained demographic questions. The following five parts contained 5-point Likert scale questions. The participants were asked to specify the extent of their agreement or disagreement using this scale. The scale ranged from "strongly agree" (1) to "strongly disagree" (5). Participants were asked about perceived usefulness, perceived ease of use (Fröhlke and Pettersson, 2015), user satisfaction (Abu-Dalbouh, 2013), user attitudes (Frishbein and Ajzen, 1975) and intention to use (Al-ragmi and Othman, 2013). The final part of the questionnaire was consisted by optional open-ended questions about their overall experience asking them what they liked or disliked to the application and their suggestions for improvements.

Since, it was difficult for the participants to fill in personally the questionnaire two researchers took interviews of the participants and answered the questionnaire accordingly.

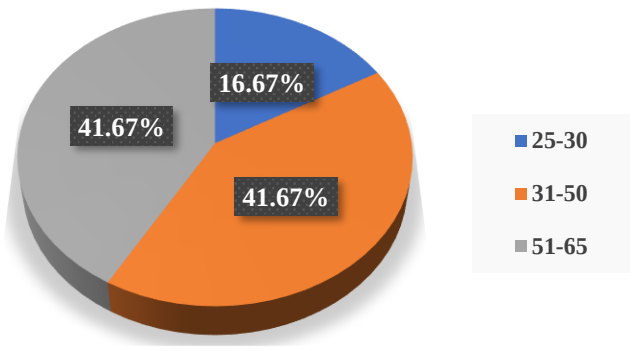
The research was conducted in February 2022 with a sample of 12 visually impaired people. It was requested from them use the proposed mobile application for 20 minutes and then interviews took place (***Figure 3***).

Figure 3. Pilot evaluation of the proposed mobile application and embossed tag



Three of them were blindless (visual acuity worse than 5%), and the rest of them of them with low visual acuity (between 5% and 30%). Among participants, 2 were in the range of 25-30 years, 5 were between the ages 35-50 and the remaining 5 between 51-65 years of age. The age information is shown in ***Figure 4***.

Figure 4. Participants' age



5.1 Research Results

Table 1 shows users' answers per questionnaire part regarding the evaluation criteria and research questions. The results are provided per user type of visually impairment and as mean of all participants.

Table 1. Evaluation per criterion

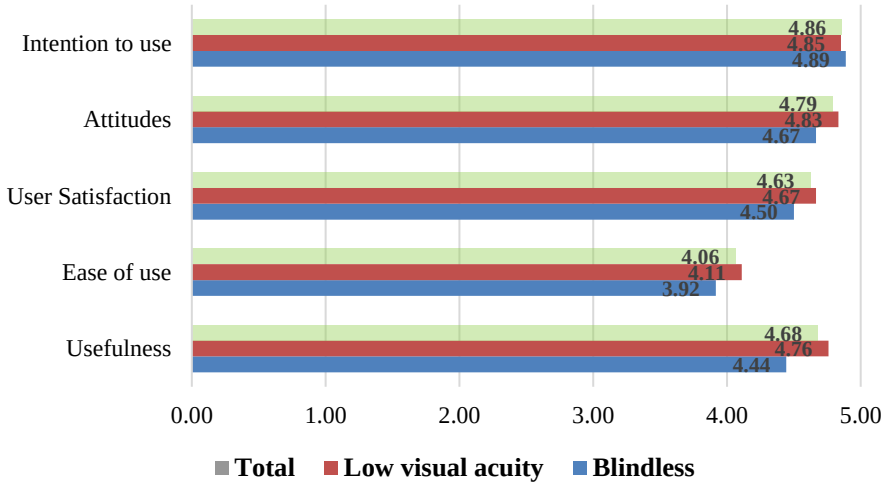
Criteria	Blindless	Low visual acuity	Total
Usefulness	4.44 (94.4%)	4.76 (96.3%)	4.68 (95.8%)
Ease of use	3.92 (66.7%)	4.11 (77.8%)	4.06 (75%)
User Satisfaction	4.5 (100%)	4.67 (97.2%)	4.63 (97.9%)
Attitudes	4.67 (83.3%)	4.83 (100%)	4.79 (95.8%)
Intention to use	4.89 (100%)	4.85 (100%)	4.86 (100%)

About 96% of the participants found useful the combination of the mobile app with the embossed QR Code. They agree at a score of 4.68 that the application is useful. Sub-results of this category reveal that participants consider as useful both before (4.58) and after (4.42) product purchase.

On the other hand, all users also found the application to be easy to use. Here there is a small difference according to the visual impairment percentage. Blindless participants have a light lower score (3.92) than the low visual acuity (4.11) in the ease of use. This is expected since they face more difficulties due to their visual impairments. Especially for the ease of use of the mobile application, blindless gave a score of 3.33 and low visual acuity users 4.22. The participants answers revealed another interesting result. Blind people could find more easily the embossed QR Code in the product (4.59) in contrast to low visual acuity users (2.89). Maybe blind people are more used to find embossed tags over products such as medicine while the low visual acuity people are based more on their, reduced, vision.

All type of participants agreed with a score more than 4.5 that they are satisfied with the proposed application and process (***Figure 5***). We got similar results for user attitudes towards the proposed application. The most impressive results are about the intention to use the application and the embossed QR Code, if it comes to the market. All users agreed with very high score (4.86) that they are going to use them whenever are available and they are going to propose the application to other people with visually impairments (4.67).

Figure 5. Participants' agreement scores per criterion



Participants proposed some improvements for both mobile application and embossed QR Codes. Regarding the application, they asked if it is possible to make QR Code scanning button even bigger, and play a sound whenever the QR Code was recognized from the app. The application was updated according to their comments. Regarding the QR Code tag they proposed to make the tag perimeter dashed line and add four embossed dots in the center of the tag. These changes would allow them to distinguish easier the QR Code tags, since in other way they may think that the embossed surface is just a part of the product design.

Finally, they mention that they liked the fact that a company cares about visually impaired people. This is showing the corporate social responsibility and should be considered as an example for other companies.

5. Discussion and conclusion

This paper proposes and validates an approach that helps people with visual impairments to acquire information about various products through audio information. With the utilization of mobile phones and embossed QR codes on the products' tags, visually impaired people have the opportunity to upgrade their shopping and after sale experience.

The proposed approach was applied by Royal company in a number of its products and was evaluated by a small number of visually impaired people. The evaluation results were more than promising. RQ1 and RQ2 were both confirmed since participants answers revealed that they found useful and ease of use the mobile application. Additionally, RQ3 was also confirmed since all the participants were satisfied from the mobile app functionality and the provided service from the company. The last research question (RQ4) was the one that had the best rating score (4.86) regarding the participants intention to use the mobile application in combination with the embossed QR Code at the future.

Even though the data came from a small group of 12 participants and might, therefore, be deemed insufficient for drawing generalizable conclusions, the findings are consistent with previous studies (Haraikawa, 2013; López-de-Ipiña, 2011) that made use of QR technology for people with visual impairments. Future work incorporates the use of embossed QR Codes in more company's products, the evaluation by a high number of visually impaired persons for longer time and in real life conditions.

Acknowledgement: This paper is part of the project "*Advanced tools for product promotion*" (ATPP), funded by the operational program "*Eastern Macedonia and Thrace 2014 – 2020*". The present study has been presented at the 14th International Conference "*Economies of the Balkan and Eastern European Countries*", EBEEC 2022, Florence, Italy (http://ebeec.ihu.gr/).

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