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NFC, WEARABLES AND QR CODE IN POS PAYMENTS: DETERMINANTS OF ADOPTION OF THE LEADING MOBILE PAYMENT TECHNOLOGIES IN EUROPE

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Abstract: Digital technologies are increasingly important in the European payment services market. The study examined NFC mobile payments, wearables payments, and QR code payments, to determine the potential for development in the European market. The paper aims to explain the factors determining consumers' intention to use or reject these technologies following the TAM methodology. Within the study, a pan-European survey using the CAWI method was conducted on a sample of n = 5,504 respondents from 22 countries. Quantitative analysis was performed using logit models. The results confirmed that the most important, positively influencing factors are the Perceived Usefulness and Perceived Ease of Use of studied payment methods. Moreover, the preference for anonymity and trust of service providers impact the intention to use mobile payment technologies. It turned out that education level and knowledge of technology play an essential role. The study showed that Europe has the market space for all three mobile payment technologies. However, NFC payments have advantages in the European market due to consumers' declared interests and widespread acceptance infrastructure among merchants.

Introduction

With technological progress, service providers and technology companies provide new solutions enabling potential users to gain new experiences. An example of the impact of technology on society is the digitalization process, which has significantly influenced society's development and the change of its current behavior, habits, and expectations towards technology. Access to the Internet and technology has meant that part of society carries out everyday activities continuously online, i.e., has access to communication links all the time, regardless of where they are, time, and circumstances. One of the most intensively developed innovations in recent years is mobile payment systems, the development and distribution of which turned out to be more challenging to implement.

This work focuses on developing critical mobile payment solutions used in physical points of sale in the European payments market. The technology that has been most successful in recent years is Near Field Communication (NFC) (Borowski-Beszta & Kiermas, 2019). It combines the payment card model with the convenience of using mobile technologies and is available in various distribution channels, i.e., via smartphones or wearable devices (Borowski-Beszta & Polasik, 2020). Mobile payments with QR codes, popular in selected European

Union countries, also play an essential role. However, the implementation and spread of mobile payments are still early, so it is essential to investigate the knowledge about mobile payments in Europe and their position in the overall payment system.

This work aims to:

1. Present the main mobile technologies – NFC, wearables, and QR codes – shaping the contemporary mobile payments market in Europe,
2. Identify the factors influencing European consumers' intensions of use or rejection of mobile payments.
3. Examining the differences between factors shaping consumer interest in the three main technologies for mobile payments.

The study is based on a pan-European representative survey conducted in August 2020 on a sample of n=5,504 respondents from 22 countries. Such a large and diverse research sample allowed for examining the entire European market, setting it apart from other studies in this field that focus on a single country or a few. The rich research material enabled the exploration of three key technologies, which are typically investigated separately.

The first part of the work presents information on key mobile payment systems used in physical points of sale in European countries, i.e., NFC technology and mobile payments in QR technology. The next part of the work is the presentation of the theoretical basis, which is the starting point for the empirical analysis. The main framework used for the work is the Technology Acceptance Model by F. Davis, which has been successfully used for years to study the factors influencing the acceptance or rejection of mobile technologies worldwide. The last part of the work presents empirical research, i.e., the analysis of data obtained as part of a survey using quantitative methods, including logit modeling. The work ends with conclusions and recommendations from the conducted research.

Mobile Payments Definition

Mobile payments are a type of cashless payment that can be initiated, authorized, and completed using mobile devices, such as a smartphone (Humbani & Wiese, 2018) or a wearable device (an advanced technological solution that the user can wear – these include, among others, smartwatches and smartbands (Borowski-Beszta & Polasik, 2020). Mobile devices play a key role in this

type of payment because they are used to initiate, confirm, and finalize transactions (Kisiel, 2013; Pal, Khethavath, Chen & Zhang, 2017). This work analyzes two main categories of mobile payments: NFC mobile payments (made using smartphones and wearable devices) and mobile payments with QR codes.

NFC mobile payments originate from contactless payments with payment cards dating back to 1997. NFC mobile payments fall within the definition of mobile payments but have several different features. The leading NFC mobile payment solutions are based on the payment card instrument. The first implementation of contactless payments with payment cards took place in Hong Kong in 1997, when the Octopus system was introduced. It was the first large-scale implementation of contactless cards and was used to handle fares in public transport (Kunkowski, 2013). MasterCard, in turn, was the first international payment organization to implement contactless technology in December 2002 in the United States. Implementing the MasterCard PayPass pilot program showed many benefits associated with the contactless payment method, resulting in the spread of contactless cards in major global markets (Polasik & Kunkowski, 2009). The year 2004 turned out to be a breakthrough for the cooperation of three technology giants, i.e., Philips, Sony, and Nokia, because they jointly developed the NFC standard, founded the NFC Forum, and then started promoting NFC applications (McHugh & Yarmey, 2012).

To implement NFC contactless payments in Mastercard and Visa solutions, NFC payment systems use procedures and communication channels created for contactless cards. The NFC device exchanges data with the EFT-POS terminal, and further information transfer in the payment system occurs only on the terminal side. Payment transactions using NFC can also be made offline, bypassing communication with the bank server issuing a given payment instrument (Polasik, 2014). In turn, contactless ATMs are almost always online. Thanks to this, "NFC mobile payments constitute a common part of the concepts of mobile and contactless payments [...], and within each of these terms, there are other solutions with clearly different characteristics" (Polasik, 2014). The combination of many different features makes NFC mobile payments attractive in terms of convenience and speed of transaction execution for individual customers. A mobile device with NFC eliminates the need for a plastic card and wallet. An innovative timing study conducted by M. Polasik in the initial phase of introducing NFC technology to the Polish payment services market showed that NFC mobile payments are competitive in terms of transaction execution time for cash and contactless payment cards and much

faster than payment cards authorized via using a PIN code and mobile payments requiring the consumer to enter the codes on the phone. An important conclusion from the research at that time was that it took customers much less time to take out a smartphone and prepare it for a transaction than to take out a payment card from the wallet (Polasik, Górka, Wilczewski, Kunkowski, Przenajkowska & Tetkowska, 2013).

NFC technology has created enormous potential for the development of mobile payments, which are considered the most revolutionary and future-proof retail payments. Making payments using a mobile device is becoming easier and more accessible, and the level of convenience of use is also increasing (Alalwan, Baabdullah, Al-Debei, Raman, Alhitmi, Abu-ElSamen & Dwivedi, 2024). Therefore, the natural development of contactless payments will be a gradual transition from card payments to NFC mobile payments using the same extensive network of EFT-POS contactless payment terminals (Kunkowski, 2013). Wearable devices are also a promising distribution channel for NFC mobile payments.

The Impact of Wearables on Payments

Wearable devices have set a new technological trend that focuses on a solution with a particularly distinctive feature, i.e., the wearability of technology. Thanks to the possibility of equipping clothes with technology, an additional benefit is achieved – always having technology. Additionally, these devices allow consumers to replace their smartphones with smartwatches or wristbands. The functionalities of wearables include not only sports (Wang, 2015) or health functions (Chang, Xu, Wong & Mendez, 2019; Reeder & David, 2016), but also payments (Borowski-Beszta & Polasik, 2020, 2022). Thanks to the last function, wearable devices are one of the innovative elements of the European payment system because they can be used to make NFC contactless mobile payments. Due to the dynamics of the development of wearable devices, which are characterized by introducing a high level of innovation in a relatively short period, this technology is a new and promising research area. Payments using wearable devices are currently offered by many payment institutions around the world, including Apple (Apple Pay) (www1), Google (Google Pay) (www2), Xiaomi (Xiaomi Pay) (www3), Garmin (Garmin Pay) (www4), as well as Fitbit, which until 2022 offered the Fitbit Pay system, currently working with Google Pay (www5).

QR Code Payments as an Alternative

An essential solution for making mobile payments is mobile payment systems based on QR codes. This is another cashless form of payment using dot matrix codes developed by Denso Wave (HARA, 2019), which can be displayed both on the smartphone screen and, for example, printed. QR codes contain transaction data and enable quick mobile payments (Ramos de Luna, Liébana-Cabanillas, Sánchez-Fernández & Muñoz-Leiva, 2019). QR code payments have been most popular in Asian countries, with systems such as WeChat and AliPay (Polasik, Widawski, Keler & Butor-Keler, 2021). However, their popularity is growing in some European countries, e.g., in Belgium, where one of the most popular mobile payment systems is Bancontact by Payconiq (www6). These codes have many uses and also work very well for city payments (Di Pietro, Guglielmetti Mugion, Mattia, Renzi & Toni, 2015), as a quick form of purchasing tickets for consumers.

Mobile Payments in Europe

In our study, we asked respondents in individual European countries whether they already use NFC, wearables, and QR payments, and whether they intend to use them in the future. In Table 1, we have compiled statistics for the use and interest in individual types of mobile payments. Paying with NFC technology is already quite common in the EU, with a reach exceeding 25%, twice as much as wearables, and nearly three times more than QR payments. We can say that the success of NFC is significant, and one of the reasons is a well-developed network of contactless payment systems that both NFC and wearables (EBC SPACE) can leverage. However, these systems do not support payments via QR codes.

Table 1. Use and Intention to Use the Three Main Mobile Payment Technologies in Europe

Country	NFC		Wearables		QR code	
	Use	Willingness	Use	Willingness	Use	Willingness
	%	% of agree and strongly agree answers	%	% of agree and strongly agree answers	%	% of agree and strongly agree answers
Austria	20	39	7	19	7	19
Belgium	17	52	8	24	35	40
Bulgaria	12	46	4	36	2	28
Czechia	29	30	16	12	15	17
Denmark	21	40	11	19	13	26
Finland	23	42	6	24	6	18
France	20	53	20	34	6	32
Germany	20	35	9	21	7	23
Greece	15	48	9	28	8	22
Hungary	19	41	8	31	9	24
Ireland	32	63	18	31	4	21
Italy	20	42	12	27	7	30
Lithuania	18	64	10	48	11	48
Netherlands	29	47	11	29	34	34
Norway	24	42	9	24	6	19
Poland	37	65	15	46	5	41
Portugal	12	61	8	41	9	46
Romania	25	53	9	32	5	32
Slovakia	29	35	15	18	9	18
Spain	24	47	11	30	6	31
Sweden	31	49	8	24	21	34
United Kingdom	37	56	20	41	3	27
Total	25	50	12	31	9	30

S o u r c e : PayTchImpact.EU research, weighted data based on gender, age, and location.

However, considering the differences between countries, the highest percentage of use of NFC mobile payments is reported in Poland, the United Kingdom (37%), Ireland (32%), and Sweden (31%). NFC mobile payments are most rarely indicated by consumers from Bulgaria, Portugal (12%), and Greece (15%). However, regarding the willingness to use NFC mobile payments, in all the countries surveyed, the share of respondents interested in using NFC in the near future is 30%. The highest interest was shown by consumers from Poland (65%), Ireland (63%), and Lithuania (66%).

When it comes to wearable devices, this is a less frequently used product. On average, only 12% of consumers use it for payments, and this level of popularity is similar across Europe. However, significant differences were found when it comes to interest in using wearable devices in the future. Consumers from 4 of the 22 surveyed countries showed a willingness to use wearable devices at a level higher than 40%, and the most significant interest was shown by consumers from Lithuania (48%), Poland (46%), Portugal (41%), and the United Kingdom (41%). It is worth paying attention to Bulgaria, which takes fifth place (35%). Despite the low popularity of wearable devices and NFC mobile payments among Bulgarians, they are willing to use such solutions.

Analyzing mobile payments with QR codes brings a radically different picture than the above-described technologies. Consumers from Belgium (35%) and the Netherlands (34%) are undoubtedly at the forefront, which may be because there are already two well-functioning QR mobile payment systems in these countries – i.e., Payconiq by Bancontact in Belgium, as well as iDEAL in the Netherlands. In other countries, the percentage of users who use QR mobile payments is much lower, and the average for the entire sector is lower – 9%. It should be noted, however, that again, as in the case of wearable devices, the most significant potential for using QR mobile payments is perceived by consumers from Lithuania (47%), Portugal (46%), Poland (41%), and Belgium (40%).

Research Model

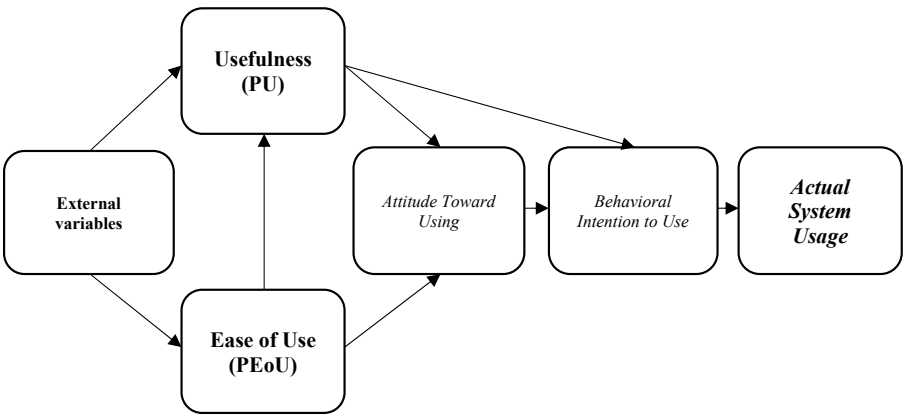
We used the Technology Acceptance Model framework as a starting point for developing the research model. The Technology Acceptance Model (TAM), developed based on the Theory of Reasoned Action, was presented by F. Davis in 1986. The TAM model makes it possible to examine and explain the factors influencing the use or rejection of selected technological innovations. This model,

presented in Figure 1, is the basis for determining factors influencing the beliefs, behaviors, and intentions of potential users, which simultaneously translates into the actual use of the selected innovation. The two key factors that form the basis of the discussed model are (Davis, Bagozzi & Warshaw, 1989):

- Perceived Usefulness – PU;
- Perceived Ease of Use – PEoU.

Perceived Usefulness (PU) is the level to which an individual believes that a selected technological innovation will help increase his or her performance when completing tasks. However, the second primary factor – perceived ease of use (PEoU), refers to the degree to which the user believes that using a given innovation will take place without effort (Davis et al., 1989).

Figure 1. The Classic Form of F. Davis' Technology Acceptance Model



S o u r c e : own study based on: Davis, Bagozzi and Warshaw (1989).

The classic version of the TAM model assumes that perceived usefulness (PU) and perceived ease of use (PEoU) are directly influenced by external factors (External Variables – EV). In turn, the intention to use (Behavioral Intention – BI) of a selected system or technological innovation is influenced by the overall attitude of users towards a given system (Attitude) and Perceived Usefulness (PU). The factors mentioned above may ultimately translate into the actual use of technology among consumers (Polasik & Kumkowska, 2015).

The Technology Acceptance Model is successfully used among researchers of technology acceptance by users worldwide. It has been used in a wide range

of research, including financial innovations such as mobile banking (Jeong & Yoon, 2013; Muñoz-Leiva, Climent-Climent & Liébana-Cabanillas, 2017; Polasik, Wisniewski & Lightfoot, 2012), NFC mobile payments (Pal, Vanijja & Papasratorn, 2015; Ramos-de-Luna, Montoro-Ríos & Liébana-Cabanillas, 2016), as well as QR code payments (Yan, Tan, Loh, Hew & Ooi, 2021). This model is also a research tool used by authors examining wearable devices, including smartwatches and smartbands (Borowski-Beszta & Polasik, 2020; Chang, Lee & Ji, 2016). Research conducted using the TAM model concerned both non-financial contexts (Morosan, 2011), as well as financial (Leong, Hew, Tan & Ooi, 2013; Mun, Khalid & Nadarajah, 2017; Patil, Tamilmani, Rana & Raghavan, 2020; Polasik & Kumkowska, 2015; Ramos-de-Luna et al., 2016). With technological progress, an increasing number of wearable devices enabling contactless payments have appeared on the market. Therefore, the attention of researchers has also been directed to contactless payments with wearable devices (Borowski-Beszta & Polasik, 2020; Chang et al., 2016; Chuah, Rauschnabel, Krey, Nguyen, Ramayah & Lade, 2016; Kim & Shin, 2015). The widespread use of the TAM model and its derivatives in research on payment innovations suggests the application of its assumptions and main constructs for this work.

Methodology and data

The study is based on a pan-European representative survey conducted using the CAWI method on a sample of n=5,504 respondents from 22 countries in August 2020. The pan-European research was carried out under a grant from the National Science Center, entitled "The impact of FinTech development and legal regulations on innovations in the payment services market in the European Union: financial sector strategies and consumer needs" No. 2017/26/E/HS4/00858. The research agency collected the survey responses using the Dynata research panel. The study is representative of the characteristics of European Internet users and included, among others, age, gender, and place of residence.

The analysis considered three payment methods separately: NFC (understood as digital card, Google Pay, or Apple Pay payments via a smartphone), wearables, and QR. NFC and wearables can be treated as the same solution in the technology dimension of data exchange with payment terminals. Still, in the dimension of consumer experiences, they have somewhat different characteristics. For instance, smartphones are a more widespread technology used

for various purposes, while wearables are a relatively newer solution. In the study, respondents were asked about their intention to use the tested payment technologies in the near future (12 months). In the analysis, three models were constructed for each payment method. The variable testing intention is an ordinal variable, so an ordered logit was used to explain it. Different combinations of independent variables were adopted for each model from a set comprising three groups of variables.

Table 2. Variables Description

Group	Short name of variable	Description	Scale
use	Declaration of actual use of mobile payment	Dependent variable (explained) 1 – separate for each of the three methods: NFC / QR / wearables.	ordered 1–5 *1 – strongly none* *2 – rather none* *3 – neither none or yes* *4 – rather yes* *5 – strongly yes*
willingness	Declaration of intent to the use mobile payment in the near future	Dependent variable (explained) 2 – separate for each of the three methods: NFC / QR / wearables.	ordered 1–5 *1 – strongly none* *2 – rather none* *3 – neither none or yes* *4 – rather yes* *5 – strongly yes*
TAM (Group A)	*Usefulness*	Perceived usefulness contruct. Construct of variables related to safety, supporting household budgets, and perceived accessibility of given methods.	continuous *1 – the least usefulness* *5 – the most usefulness* *orthogonalized to avoid corellation with other variables in the model*
	Ease of Use	Perceived ease of use. Construct of variables related to the convenience of paying with a given method.	continuous 1–5 *1 – the least ease of use* *5 – the most ease of use*
social attitudes (Group B)	*opinion_leader*	Construct of variables defining the consumer's self-perception as a person who provides advice to others regarding new solutions.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
	trustful	Most people can be trusted.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*

Table 2. Variables...

Group	Short name of variable	Description	Scale
	anonimity	I prefer payments for shopping to be anonymous, so that no one can see what I bought and when (e.g., paying by cash is anonymous, contrary to payment cards and smartphones).	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
	reliable	It is better to use tried and tested solutions.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
	peer_fraud_victim	Someone close to me was a victim of fraud which involved using a card or a payment mobile application.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
tech inclusion (Group B)	*apps no*	Number of aplications from following: – Fitness/healthcare applications (e.g., MyFitnessPal, Garmin, Endomondo, Huawei Health, Samsung Health, Polar, Apple Health) – Transport applications (e.g., Uber, Bolt, Freenow) – Food delivery applications (e.g., Uber Eats, TakeAway) – Anti-virus software installed on a mobile device – Applications for buying tickets in public transport – Applications for buying parking tickets	continuous *number*
	data_sharer	Sharing my personal data is not a problem for me.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
	cloud_user	My personal data stored by companies such as Google, Amazon, Facebook, and Apple are adequately protected.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*

Table 2. Variables...

Group	Short name of variable	Description	Scale
	bank_storage	When it comes to payments, I only trust banks.	ordered 1–5 *1 – strongly disagree* *2 – rather disagree* *3 – neither agree or disagree* *4 – rather agree* *5 – strongly agree*
solution availability coefficient in a given country (Group B)	*share_contactless*	An indicator assigned to a country reflecting the availability of contactless payments.	continuous *percent*
	cvm_limit	An indicator assigned to a country reflecting the limit for contactless payments without the need to enter a PIN code.	continuous *EURO*
socio-demographic (Group C)	*gender*	gender	Nominal *1 – woman* *2 – man*
	age	age	continuous *years*
	location	place of residence	Ordered *1 – Rural area* *2 – Town with less than 50 thousand inhabitants* *3 – Town between 50 thousand and 100 thousand inhabitants* *4 – City between 100 thousand and 500 thousand inhabitants* *5 – City between 500 thousand and 1 million inhabitants* *6 – City with over 1 million inhabitants*
	education	education level divided to higher and less than higher	ordered 1–2 *1 – less than higher* *2 – higher*
	income	personal income	ordered 1–11 *standardized 11 ranges with control points at the poverty line, the national minimum and the national average for each country*

S o u r c e : own study based on: PayTchImpact.EU research.

A description of the variables is presented in Table 2. The first group (Group A) includes variables related to *Usefulness* and *Ease of use*, derived from the theoretical assumptions of the TAM model. This allowed testing to what extent factors related to usability and ease of use impact the intention to use NFC, wearables, and QR payment technologies. Results of the reliability analysis of two constructs, *Usefulness* and *Ease of Use*, for all three payment methods tested, are shown in Table 3. Cronbach's Alpha parameters are consistently above the threshold of 0.60, deemed acceptable by Churchill (1979). Therefore, both constructs can be treated as representing the hidden phenomena of "usefulness" and "ease of use." The constructs *Usefulness* and *Ease of use* were related (Pearson $r > 0.55$), so to eliminate the redundancy of information brought by them to the model; orthogonalization was applied, in which one variable is transformed so that it becomes independent (orthogonal) with respect to the other variable. This means that their correlation coefficient is equal to zero.

In the second group (Group B), variables testing the level of technological involvement in areas other than payments are introduced. Technological involvement in various life areas may significantly correlate with the adoption of modern payment methods. In this block, variables such as the number of used transportation apps (*apps_no*), attitude toward cloud solutions (*cloud_user*), and willingness to share personal data with service providers (*data_sharer*) are included. It is also assumed that social factors may influence the higher-level adoption of payment methods, such as the general level of trust in others (*trustful*), perception of anonymity (*anonymity*), seeing oneself as a person who influences the purchasing decisions of others (*opinion_leader*), and the experience of encountering a fraudster personally or in the immediate surroundings using new technologies (*peer_fraud_victim*). Additionally, variables indicating the level of contactless payment acceptance in the respondent's country (*share_contactless*) and the contactless payment limit without requiring a PIN code (*cvm_limit*) are introduced. These two variables are considered at the country level, not for individual respondents.

Group C comprises socio-demographic variables: *gender*, *age*, *location* (size of the residential area), *education*, and *income*. The detailed assignment of variables to blocks and a description of the scales on which they were measured are provided in Table 2.

Table 3. Reliability Analysis of the Constructs

Payment method	Construct	Observed variable	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	n
NFC	Usefulness	wide-spread	17.5548	15.145	0.546	0.780	0.807	4829
		control over personal finance	17.4157	14.511	0.606	0.767		
		convenient	17.5419	13.895	0.629	0.760		
		safe	17.3371	13.696	0.622	0.762		
		useful mobile	17.0345	15.903	0.486	0.792		
		mobile finance	17.3988	14.649	0.504	0.791		
	Ease of Use	easy to use	20.2684	17.238	0.311	0.735	0.735	
		convenient	19.9428	17.132	0.388	0.716		
		methods overflow	19.7188	16.927	0.425	0.709		
		easy app	20.4923	16.115	0.434	0.707		
		online hardship	20.3179	15.313	0.564	0.675		
		mobile-hardship	20.1680	14.751	0.595	0.665		
		forced	20.3237	16.263	0.421	0.710		

Table 3. Reliability...

Payment method	Construct	Observed variable	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	n
wearables	Usefulness	wide-spread	17.2626	17.614	0.597	0.792	0.822	
		control over personal finance	17.1130	17.288	0.625	0.785		
		convenient	17.2330	16.174	0.649	0.780		
		safe	17.1977	16.398	0.727	0.762		
		useful mobile	16.6777	20.128	0.451	0.819		
		mobile finance	17.0000	18.846	0.483	0.815		
	Ease of Use	easy to use	20.3107	17.600	0.319	0.724	0.722	
		convenient	19.9969	17.615	0.389	0.701		
		methods overflow	19.7425	18.642	0.406	0.697		
		easy app	20.4720	17.815	0.422	0.692		
		online hardship	20.3135	16.952	0.552	0.662		
		mobile hardship	20.1905	16.479	0.573	0.655		
		forced	20.3614	17.939	0.411	0.695		

Table 3. Reliability...

Payment method	Construct	Observed variable	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	n
QR	Usefulness	wide-spread	17.0075	16.619	0.535	0.784	0.807	
		control over personal finance	16.7110	15.792	0.626	0.763		
		convenient	17.0311	15.227	0.624	0.763		
		safe	16.7632	15.177	0.704	0.744		
		useful mobile	16.2564	18.521	0.437	0.803		
		mobile finance	16.5902	17.258	0.470	0.798		
	Ease of Use	easy to use	20.1504	16.597	0.264	0.701	0.693	
		convenient	19.7433	16.529	0.319	0.682		
		methods overflow	19.3459	16.969	0.391	0.663		
		easy app	20.0934	16.146	0.407	0.657		
		online hardship	19.9336	15.442	0.530	0.625		
		mobile hardship	19.7991	14.972	0.553	0.617		
		forced	19.9786	16.330	0.392	0.661		
opinion_leader		following trends	3.0222	1.171	0.536	–	0.697	
		advising others	3.4808	1.072	0.536	–		

Source: own study based on PayTchImpact.EU research.

Results

Three ordered logit models were estimated for *Intention to Use Payment Methods* dependent variables, each of the analyzed payment methods: NFC, wearables, and QR mobile payments. The results of the estimations are presented in Table 4. Model 1 for each method includes all the variables mentioned above in Table 2. Model 2 excludes variables from Group B, while Model 3 excludes variables from Group B.

The results confirm the role of traditional TAM model constructs – usefulness and ease of use – as factors shaping the willingness to adopt new payment technologies. In each model variant for all three payment methods, *Usefulness* and *Ease of Use* are statistically significant and impact the *Intention to Use* these payment methods in the future within 12 months. These constructs determine the willingness to use of both NFC, as well as wearables and QR payments.

In the case of all three tested payment methods, the *Intention to Use* them in the future positively correlates with the consumer's self-perception as a person at the forefront of market changes (*opinion leader*). On the other hand, the social capital indicator, i.e., the level of trust in other people (*trustful*), is irrelevant in the choice of any of the methods. It can be presumed that the motives for choosing such solutions do not arise from trust in other individuals because, in the social perception, they are based on technology rather than human factors.

The lower emphasis an individual places on anonymity (*anonymity*), the greater the chance of using NFC in the future. However, the attitude towards anonymity does not play a role in the choice of wearables and QR codes payments. This may be related to the fact that in the case of NFC, the connection between the payment method and cards, for which anonymity concerns also exist, is more visible (Borgonovo, Caselli, Cillo, Masciandaro & Rabitti, 2021; Wisniewski, Polasik, Kotkowski & Moro, 2024). Preference for reliable solutions (*reliable*) is positively associated with the choice of each method. Consumers who already use cloud solutions (*cloud_user*) and have no problem sharing their data with digital service providers (*data_sharer*) and use a greater number of transportation and service mobile applications (*apps_no*) are more inclined to use NFC, wearables, or QR codes in the future.

Table 4. Models Explaining the *Intention to Use Payment Methods* Within 12 Months

	NFC						wearables						QR					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.
Usefulness	2.01	***	2.21	***	2.00	***	0.78	***	1.02	***	0.77	***	0.71	***	0.94	***	0.70	***
Ease of use	2.21	***	2.45	***	2.20	***	0.65	***	0.87	***	0.64	***	0.81	***	0.97	***	0.80	***
opinion_leader	0.20	***			0.21	***	0.50	***			0.50	***	0.49	***			0.49	***
trustful	0.00				0.00		0.01				0.02		0.05				0.05	
anonymity	0.08	***			0.08	***	0.00				0.00		0.03				0.03	
reliable	0.17	***			0.18	***	0.20	***			0.21	***	0.16	***			0.16	***
peer_fraud_vic~	-0.10	***			-0.10	***	-0.13	***			-0.13	***	-0.14	***			-0.13	***
apps	0.20	***			0.21	***	0.28	***			0.29	***	0.25	***			0.25	***
data_sharer	0.08	***			0.09	***	0.18	***			0.19	***	0.15	***			0.16	***
cloud_user	0.07	**			0.07	*	0.38	***			0.39	***	0.34	***			0.34	***
bank_storage	-0.10	***			-0.11	***	-0.20	***			-0.21	***	-0.22	***			-0.22	***
share_contactles	-0.40				-0.45		0.56				0.44		1.06	***			1.02	***
cvm_limit	0.00				0.00		0.00				0.00		0.00				0.00	
gender	0.21	***	0.28	***			0.13	**	0.28	***			0.17	***	0.31	***		
age	0.00		-0.01	***			-0.01	***	-0.02	***			0.00		-0.02	***		

Table 4. Models...

	NFC						wearables						QR					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.
location	-0.01		0.02				-0.03	*	0.03	*			-0.01		0.05	***		
education	0.09		0.18	***			0.03		0.16	***			-0.06		0.07			
income	-0.01		0.00				-0.02	*	0.00				-0.01		0.01			
cut1	5.57	***	5.40	***	5.27	***	4.54	***	1.98	***	4.83	***	5.38	***	2.50	***	5.36	***
cut2	6.50	***	6.30	***	6.19	***	5.53	***	2.83	***	5.82	***	6.37	***	3.37	***	6.36	***
cut3	8.27	***	7.99	***	7.96	***	6.91	***	4.00	***	7.18	***	7.84	***	4.65	***	7.82	***
cut4	9.75	***	9.42	***	9.43	***	8.35	***	5.28	***	8.63	***	9.39	***	6.05	***	9.37	***
Mean dependent var	3.43		3.43		3.43		2.79		2.79		2.79		2.77		2.77		2.77	
Log-likelihood	-5,933		-6,066		-5,941		-5,698		-6,162		-5,710		-5,780		-6,191		-5,786	
Schwarz criterion	12,052		12,225		12,026		11,579		12,417		11,561		11,744		12,474		11,713	
S,D, dependent var	1.35		1.35		1.35		1.39		1.39		1.39		1.34		1.34		1.34	
Akaike criterion	11,910		12,154		11,916		11,440		12,347		11,453		11,604		12,404		11,605	
Hannan-Quinn	11,960		12,179		11,954		11,489		12,372		11,492		11,653		12,428		11,644	

Table 4. Models...

	NFC						wearables						QR					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.	Coof.	Sig.
Number of cases 'correctly predicted'	2,367 (49.0%)		2,354 (48.7%)		2,358 (48.8%)		1,702 (40.4%)		1,496 (35.5%)		1,700 (40.3%)		1,712 (40.5%)		1,455 (34.4%)		1,724 (40.8%)	
Likelihood ratio test: Chi-square	(18) = 3,773.05 [0.0000]		(7) = 3,506.8 [0.0000]		(13) = 3,757.11 [0.0000]		(18) = 2,676.71 [0.0000]		(7) = 1,747.44 [0.0000]		(13) = 2,653.01 [0.0000]		(18) = 2,496.28 [0.0000]		(7) = 1,674.43 [0.0000]		(13) = 2,484.69 [0.0000]	
n	4,829						4,214						4,225					

S o u r c e : own study based on: PayTchImpact.EU research.

Personal experiences with fraud related to the use of modern technologies (*peer_fraud_victim*) have a significant and statistical negative impact on the willingness to use the tested payment methods in the future. Individuals who feel that their personal data are secure only when banks store them (*bank_storage*) will have less inclination to use new payment methods in the future, and this influence is statistically significant. Trust in banks is thus a factor inhibiting the development of mobile payments; however, this indicator can be considered an indirect measure of technological conservatism.

In countries where the share of contactless transactions (*share_contactless*) is smaller, there is a statistically significant positive attitude towards using QR technology in the future. This is evident because QR may be perceived as a desirable technology in these markets with underdeveloped payment infrastructure, similar to the case of mobile payments in Kenya (Van Hove & Dubus, 2019). On the other hand, the prevalence of contactless terminals in other countries may render the introduction of QR codes for payments unnecessary. It should be noted that since 2020, all payment terminals in Europe that support Mastercard and Visa cards have been required to support contactless technology. Consequently, the acceptance network for NFC payments is extensive. These findings confirm the influence of external network effects on the payment services market. Such effects amplify interest in widely adopted technologies with an established acceptance network in this context. Conversely, for less prevalent solutions, such as QR codes in Europe, network effects pose a barrier to growth (Johnson, 2019; Van Hove, Polasik & Kotkowski, 2024).

In the case of each tested technology, men (*gender*) are more willing to use them in the next 12 months. This observation aligns with other studies in the area of attitudes toward new technologies for women and men (Chen & Shih, 2014; Venkatesh & Morris, 2000). The age factor achieves statistical significance only in Model 2, where variables related to attitudes and digital inclusion are not considered. It can be concluded that *age* is not a factor conducive to the *Intention to Use* NFC, wearables, and QR codes in the future; rather, it is a variable related to digital inclusion associated with age. A similar relationship occurs in the case of having a higher education (*education*), where it is statistically significant in the demographic model but not in the full model because, as we can assume, variables related to digital inclusion are associated with education. Therefore, the group on which the development of mobile payments will be based in the near future consists of young, better-educated individuals, dig-

itally engaged in areas such as cloud solutions or service applications, perceiving themselves as opinion leaders.

Conclusions

Mobile financial technologies undoubtedly already play an essential role in the social lives of European consumers. Within Everett Rogers's theory of innovation diffusion (Rogers, 2003), not only payments via wearables and QR, but also NFC payments, are at the early adopters stage. We can undoubtedly talk about well-prepared ground for the next phase of the early majority. The research showed a potential for developing mobile services in the European market, both for NFC mobile payments and wearable devices, which are currently equipped with NFC antennas and QR code payments with optical interfaces. However, the market space is not equal for the tested payment methods. According to the respondents' declarations, NFC mobile payments have the highest potential for dynamic growth in the near future.

Convincing consumers of their usefulness and ease of use proves to be crucial for all three mobile payment methods. However, the popularity of selected payment methods is determined not only by factors from the TAM model, such as Perceived Usefulness and Perceived Ease of Use. The determinants of the interest in mobile payments are complex – consumers with knowledge about mobile payments may be more willing to use them; therefore, educating consumers in digital finance is very important. It remains unclear whether mobile payments will contribute to reducing financial exclusion, as observed in Asia and Africa (Senyo & Osabutey, 2020; Zhang, Zhang & Gong, 2022), or if they will primarily cater to the most technologically advanced social groups, limiting their positive impact.

The choice of a specific payment technology by consumers is strongly influenced by the availability of payment acceptance infrastructure at points of sale. Currently, in Europe, contactless payments and wearables hold a significant advantage due to the high density of contactless payment terminals in most countries. This generally has a negative impact on the adoption of QR code payments. It should also be noted that this study did not include local mobile payment systems that were not widely used in physical points of sale at the time of the survey. This pertains particularly to alternative systems such as BLIK in Poland, Swish in Sweden, or Bizum in Spain. In the future, their devel-

opment holds significant potential to reshape the mobile payments landscape in Europe. Similarly, the growth of the Wero mobile wallet under the European Payments Initiative (EPI) could have a comparable transformative impact (Jacob, Burelli, Großkurth, Kasch, Bunge & Büttner, 2024). Therefore, the issue of financial inclusion, the impact of network effects, and the development of alternative mobile payment systems remain prospective topics for future research.

The above research results may have some limitations due to the fact that the survey was conducted in the second half of 2020. However, there are several factors that make the obtained results still relevant to the situation on the retail payments market. Firstly, from the time of the survey to the present, no new mobile payment method has appeared in Europe. Therefore, the NFC, wearables, and QR code technologies studied remain the only ones widely available for payments at physical points of sale. Secondly, the study was already conducted during the COVID-19 pandemic, which had a positive impact on the interest in alternative payments to cash (Daragmeh, Lentner & Sági, 2021). Therefore, the impact of the pandemic has already been taken into account in our study.

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APPENDIX

Table 5. Summary statistics

variable	N		Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Variance	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Minimum	Maximum
	Valid	Missing												
widespread NFC	4,829	675	3.27	0.01	3.00	3.00	0.95	0.90	-0.24	0.04	0.07	0.07	1	5
widespread wearables	4,365	1,139	3.16	0.02	3.00	3.00	1.19	1.41	-0.17	0.04	-0.74	0.07	1	5
widespread QR	4,328	1,176	3.00	0.02	3.00	3.00	1.15	1.33	-0.04	0.04	-0.72	0.07	1	5
control over personal finance NFC	4,829	675	3.40	0.01	3.00	3.00	1.00	1.00	-0.30	0.04	-0.02	0.07	1	5
control over personal finance wearables	4,338	1,166	3.32	0.02	3.00	3.00	1.20	1.43	-0.32	0.04	-0.65	0.07	1	5
control over personal finance QR	4,300	1,204	3.29	0.02	3.00	3.00	1.18	1.39	-0.30	0.04	-0.64	0.07	1	5
convenient NFC	4,829	675	3.27	0.02	3.00	3.00	1.08	1.16	-0.38	0.04	-0.24	0.07	1	5
convenient wearables	4,417	1,087	3.11	0.02	3.00	3.00	1.36	1.85	-0.19	0.04	-1.10	0.07	1	5
convenient QR	4,392	1,112	2.91	0.02	3.00	3.00	1.29	1.66	-0.04	0.04	-1.02	0.07	1	5
safe NFC	4,829	675	3.33	0.01	3.00	3.00	1.00	1.00	-0.36	0.04	0.04	0.07	1	5

Table 5. Summary...

variable	N		Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Variance	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Minimum	Maximum
	Valid	Missing												
safe wearables	4,408	1,096	3.19	0.02	3.00	3.00	1.22	1.50	-0.26	0.04	-0.78	0.07	1	5
safe QR	4,368	1,136	3.21	0.02	3.00	3.00	1.19	1.43	-0.30	0.04	-0.69	0.07	1	5
easy to use NFC	4,829	675	3.60	0.01	3.50	3.00	0.97	0.94	-0.44	0.04	0.14	0.07	1	5
easy to use wearables	4,329	1,175	3.53	0.02	4.00	3.00	1.21	1.46	-0.51	0.04	-0.53	0.07	1	5
easy to use QR	4,306	1,198	3.40	0.02	3.00	3.00	1.18	1.39	-0.39	0.04	-0.58	0.07	1	5
useful_mobile	5,504	0	3.71	0.01	4.00	4.00	0.99	0.99	-0.72	0.03	0.35	0.07	1	5
mobile_finance	5,504	0	3.33	0.02	3.00	4.00	1.20	1.43	-0.44	0.03	-0.58	0.07	1	5
methods_overflow	5,504	0	3.01	0.01	3.00	3.00	1.11	1.24	0.11	0.03	-0.55	0.07	1	5
easy_app	5,504	0	3.70	0.01	4.00	4.00	1.04	1.07	-0.72	0.03	0.22	0.07	1	5
online_hardship	5,504	0	3.18	0.01	3.00	3.00	1.08	1.17	-0.04	0.03	-0.39	0.07	1	5
mobile_hardship	5,504	0	3.31	0.02	3.00	3.00	1.14	1.29	-0.13	0.03	-0.63	0.07	1	5
forced	5,504	0	3.18	0.01	3.00	3.00	1.11	1.22	-0.04	0.03	-0.61	0.07	1	5
opinion_leader	5,504	0	3.20	0.01	3.00	3.00	0.95	0.90	-0.32	0.03	-0.15	0.07	1	5
trustful	5,504	0	2.72	0.01	3.00	3.00	1.08	1.16	-0.05	0.03	-0.72	0.07	1	5
anominity	5,504	0	2.72	0.02	3.00	3.00	1.12	1.24	0.27	0.03	-0.50	0.07	1	5
reliability	5,504	0	2.30	0.01	2.00	2.00	0.87	0.75	0.48	0.03	0.34	0.07	1	5

Table 5. Summary...

variable	N		Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Variance	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis	Minimum	Maximum
	Valid	Missing												
peer_fraud_victim	5,504	0	3.52	0.02	4.00	5.00	1.33	1.76	-0.35	0.03	-1.11	0.07	1	5
apps_no	5,504	0	1.77	0.02	1.00	0.00	1.73	3.00	0.79	0.03	-0.36	0.07	0	6
data_sharer	5,504	0	2.69	0.02	3.00	3.00	1.14	1.29	0.10	0.03	-0.74	0.07	1	5
cloud_user	5,504	0	2.85	0.01	3.00	3.00	1.08	1.16	-0.08	0.03	-0.52	0.07	1	5
bank_storage	5,504	0	3.52	0.01	4.00	4.00	0.98	0.96	-0.55	0.03	0.17	0.07	1	5
share_contactl~	5,504	0	0.91	0.00	0.93	1.00	0.08	0.01	-0.71	0.03	-0.70	0.07	0.74	1
cvm_limit_2019	5,504	0	215.55	10.91	30.00	25.00	809.41	655,141.96	5.62	0.03	30.31	0.07	20	5,000
gender	5,504	0	1.49	0.01	1.00	1.00	0.50	0.25	0.12	0.03	-1.78	0.07	1	4
age	5,504	0	47.04	0.22	47.00	67.00	16.31	266.03	-0.02	0.03	-1.19	0.07	18	100
location	5,504	0	2.77	0.02	2.00	1.00	1.57	2.48	0.62	0.03	-0.68	0.07	1	6
education	5,504	0	1.47	0.01	1.00	1.00	0.50	0.25	0.13	0.03	-1.98	0.07	1	2
income	5,504	0	8.52	0.04	8.00	7.00	2.87	8.26	-0.06	0.03	-0.06	0.07	1	14

S o u r c e : own study based on: PayTchImpact.EU research.