Willingness to accept social robots in museums according to age: An exploratory study of Spanish visitors

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Purpose
The aim of this exploratory study is to identify the factors that influence the acceptance of social robots in museum environments and determine if this influence depends on visitor age.

Methodology
Data collected from an electronic questionnaire include 433 responses from Spanish visitors. We divided the sample into two groups according to age: under or over 30 years old. We subjected the variables proposed by De Kervenoael *et al.* (2020) to exploratory factor analysis to test their applicability to museums. After identifying the factors, we applied an ANOVA test to determine whether there were age-related differences between the factors related to robot acceptance in museums.

Findings
We developed a multidimensional instrument for measuring willingness to accept social robots in museum contexts. Willingness is determined by three factors: museum visitor experience, empathy, and personal engagement. The younger individuals (under 30 years old) have a higher degree of acceptance than visitors over 30.

Originality
Learning how visitors perceive the presence of robots in museum environments requires a great deal of research. Robot use in museums is still very low, although the kind of technology that robots exemplify could prove to be a major draw for young people and contribute significantly to the future of museums.

Keywords: young´s social robot acceptance, human-robot interaction, museums, young people, experience, empathy, personal engagement.

Introduction

Museums nowadays recognize the value of cultivating interest in younger generations, and they have implemented various technologies to attract young people, keep their attention, and engage them more fully (Lo *et al.,* 2019). Appropriate uses of interactive technologies naturally result in engagement in museum learning (Harrison, 2011).

Technological developments in recent decades have made it possible to prove concepts with service robot applications that add value to the museum experience by complementing other current technologies (e.g., audio-guides, multimedia guides, and personal technologies) (Giuliano *et al.,* 2015). The use of social robots has been explored within a museum setting mainly for guiding tours (Yousuf *et al.,* 2013, Pang *et al.,* 2018). According to Levere (2018), robots can answer visitors' questions and tell stories, using voice, gestures (Bandeira et al., 2015), and an interactive touch screen. They also dance, play, and pose for selfies. Robots interact with visitors, welcoming them, guiding to find a work (Behan and O'Keeffe, 2008), sharing information and the museum's contents, in some ways replacing the human guide (Dal Bò, 2020).

These kinds of robots are widely seen as machines capable of carrying out complex series of actions and autonomous decision making based on the data they receive from various sensors and other sources (i.e., the sense-think-act paradigm). They adapt to the situation; thus, they can learn from previous episodes. Robots in a frontline service setting are the interaction counterpart of a customer and therefore can be viewed as social robots (Wirtz *et al.,* 2018).

Museum management is a traditional object of attention for managers, policymakers and scholars. The field provides numerous examples of how technology enhances museum services and how insights can be drawn therefrom to learn more and incorporate rewarding new technologies into museums (Virto and López, 2019). However, despite the importance of service robot technology for the culture and services sector, it is not yet considered a mature field of research (Ivanov *et al.*, 2019). The majority of the published papers on robot use focus on hotel services and restaurants; only a few (3.82%) address museums (Ivanov *et al.,* 2019). The most common research approaches hail from the fields of engineering and robot design and architecture, leaving a great deal of room for work from the standpoint of other disciplines. Furthermore, research into social robot acceptance and robots from the visitor's prism are of interest since these topics are still largely unexplored.

One reason for this particular research project is the importance of technology for services and especially for museums (Virto *et al.*, 2017) in order to attract the young public. Museums need to adopt new technologies, new exhibit and communication formats, and new ways to relate to the traditional public (Bakhshi and Throsby, 2010; Camarero *et al.*, 2015). Social robots may be a good way to open up museums to a younger public (millennials) that is considered adept at and accepting of new technologies (Ivanov *et al.*, 2018). Furthermore, in the case of Spain, millennials make up the segment with the lowest museum attendance. We consider that technological innovation could open up museums and bring them closer to new potential segments such as youth, since the latest available data show a rise in virtual museum tours over the Internet, including an 8.3% increase in virtual tours taken by our study's target population (Ministry of Culture and Sports, 2020). According to official data from Spain's Ministry of Culture and Sports (2020), only 40% of Spanish people attend museums at least once a year. This low rate of attendance could be raised by the use of technologies and more specifically robots, as a good starting point for interesting young people and thus improving museums' future viability.

The second reason for this research is that human willingness to accept social robots in the particular segment of the service sector occupied by museums has received almost no attention from the academic literature (Pan *et al*., 2015; Ivanov *et al*., 2019). Burgard *et al.* (1998) concluded more than two decades ago that there was a real need for research in the area of human-robot interaction and human willingness to accept robot technologies. A decade later, Nomura *et al.* (2007) concluded that, although there had been some psychological research into visitors' evaluations of robots at science museums, it was limited to individual impressions of specific robots behaving alone. Most of the literature focuses on experiments with museum guide robots (Faber *et al.,* 2009) and their interactions with humans (Rashed *et al.,* 2015), but from the engineering and software programming standpoint.

Our aim is to fill this gap by analyzing robot acceptance in museums from the perspective of visitors. To this end, we measured museum visitors' willingness to accept robots in a museum environment. The results show that younger visitors are more willing to accept social robots in museums than older visitors. This study makes a valuable contribution to the theory and practice of social robot use in museums.

Theoretical background

Social robots in museums

Cultural organizations in general and museums in particular are immersed in increasingly complex environments (García-Muiña *et al.,* 2019). Some authors, such as Alén *et al.* (2015) refer to them as "hypercompetitive" contexts. Museums have been facing dramatic competitive changes for decades (Gilmore and Rentscheler, 2002). Under such conditions, when these institutions aim for a position of sustained competitive advantage, innovation management plays a strategic role role in attaining a position of sustained competitive advantage (García-Muiña *et al.,* 2019). An empirical understanding of the use of technology in museums and more specifically visitors' acceptance of social robots has become a necessity for understanding the future of the sector. Museums today recognize the need for creating a local, educational, intellectual, entertaining, engaging experience for their visitors. The ultimate goal of integrating new media technology is to enhance visitors' overall museum-going experience (Lo *et al.,* 2019).

Museums have implemented several technological innovations, such as mobile applications, audio guides, 3D virtual tours, and QR codes so visitors can watch videos on electronic devices during their visit. However, we find only a few examples of social robots in museums. Social robots are defined by Wirtz *et al.* (2018) as "system-based autonomous and adaptable interfaces that interact, communicate and deliver service to an organization's customers" (p. 909). The use of social robots requires value creation and fulfilment of service quality expectations (De Kervenoael *et al.,* 2020). In this sense, the use of robots in museums could improve visitors´ experience.

A review of some of the applications of robots in museums reveals a small number of examples. One robot used in museum tours is REEM, which is designed to provide service in public places, as reported by Serrano (2011). Robots can also serve as guides in different languages or make 3D reconstructions of poorly preserved monuments. Some museums are already using them for these tasks. For example, the German Museum of Technology in Berlin incorporated Tim, a robot that does guide work, in 2016.

Without a doubt the most well-known case is the Smithsonian Institution complex in Washington (the National Museum of African American History and Culture, the Hirshhorn Museum and Sculpture Garden, the National Museum of African Art, and the Smithsonian Castle) which deployed six Pepper robots. Pepper is capable of identifying the emotions of joy, sadness, anger, and surprise. It also identifies a smile, a frown, tone of voice, the lexical field each person uses, and non-verbal expressions such as the angle of the head. Dialogue with its interlocutor and facial expression recognition are the two main engines that help Pepper adapt its attitude to improve its relationship with the user. Pepper is happy if the user is happy and tries to comfort the user if he or she is sad (Gil, 2018). To interact with visitors, Pepper requires the support of museum staff to provide it with available content to start with. The more people interact with the robot, the more an open museum can be built, thanks to the connections Pepper can activate with other people (Dal Bò, 2020).

Nowadays, many museums use artificial intelligence, but few use the robot system in their rooms or spaces. As indicated by Levere (2018), quite a few museums prefer the route of the chatbot. One example is the Akron Art Museum’s Dot, a virtual chatbot guide accessed through the messaging system of the Facebook social platform. The Museum of Tomorrow in Rio de Janeiro has a chatbot as well; it worked with IBM to develop the IRIS+ chatbot, which uses IBM's Watson artificial intelligence technology. Upon arrival, museum visitors receive a card embedded with a chip to use IRIS+.

Spanish museums have not yet implemented robotics. Some of them in fact do not even include much technology beyond virtual visits on their website or audio guides. Why? Museums with robot hosts reap greater benefits, both in terms of increased visitor numbers and in terms of robots’ ability to draw in new visitors and learn about the consumers of the museum’s services. The information collected from visitors can help museums analyze visitor comments (as The Museum of Modern Art in New York does), analyze visitor behavior, (as The Broad does in Los Angeles), and track how long visitors stay in the galleries (as the Art Institute of Chicago does). All of this encourages better museum development and resource-generating potential, since by assessing and evaluating visitors, museum directors can improve future visitor experiences.

The most outstanding and interesting feature of a museum service robot is its ability to display as much information as possible about the culture the museum curates. The robot knows where every piece is, not only the museum’s showstoppers, and can encourage visitors to go see less well-known items, thus giving visitors the opportunity to expand their artistic knowledge and giving the museum a means of developing often-overlooked pieces’ artistic potential.

Technology acceptance models

Technology acceptance models are traditionally supported by theories drawn from disciplines such as psychology and sociology, given their ability to explain human behavior in different circumstances. These theories include the Theory of Reasoned Action (TRA) (Fishbein and Azjen, 1975, the Theory of Planned Behavior (Ajzen, 1991), and Diffusion of Innovation (DOI) Theory (Rogers, 2010).

Since Davis (1989) published his Technology Acceptance Model (TAM) based on the Theory of Reasoned Action (Fishbein and Azjen, 1975) to understand the perceived ease of using technology and the perceived usefulness of technology, academic literature has evolved towards other models that consider other aspects, such as the social, the emotional, or the relational aspects (Stock and Merkle, 2018). A later model proposed by Davis *et al.* (1992) showed that not only usefulness, but also enjoyment fully mediate how perceived output quality and perceived ease of use affect usage intentions. Later, Igbaria *et al.* (1994) presented a model where users are motivated to accept new technology through factors such as perceived usefulness, computer anxiety, computer satisfaction, and perceived fun. Another widely accepted model is the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Venkatesh *et al.,* 2003), which incorporates users' expectations regarding TAM, plus other factors, such as social influence and facilitating conditions.

Researchers have used these models to try and conceptualize and operationalize the various dimensions of human-robot interaction to explain interactions with social robots (Tussyadiah and Park, 2018; Primawati, 2018). Various authors have approached the subject through experiments, analyzing the psychological consequences of human-robot interaction (Aoki *et al.,* 2011) and analyzing human interaction with bartender robots (Loth *et al.,* 2015) or restaurant robots (Lee *et al.,* 2018). Lee *et al.* (2018) applied the TAM model with trust, interactivity, and quality of output as the variables in interviews with managers or deputy managers of restaurants in Taiwan. Tonkin *et al.* (2018) analyzed the user experience of HRI at check-in counters and premium lounge and gate at Sydney Airport with a social humanoid robot through the USUS framework. The USUS model (Weiss *et al.,* 2009) is a user-centered evaluation framework for collaboration between humans and humanoid robots. It is founded on a system of indicators grouped by usability, social acceptance, user experience, and societal impact.

Some tools already exist for measuring HRI, such as the Godspeed questionnaire series proposed by Bartneck *et al.* (2009), which measures users' perceptions of robots. This is a consistent set of five questionnaires rating a robot's anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety on a 5-point scale. Ivanov *et al.* (2018) used another questionnaire to evaluate young Russian adults' attitudes towards the potential use of robots in hotels. The questionnaire consisted of 53 individual questions, divided into several blocks of questions: (i) the respondents' attitudes towards the (potential) use of robots in general and robots in hotels; (ii) the respondents' opinions about the acceptability of various activities that robots could perform in a hotel; (iii) the appearance of the robot (machine-like vs. human-like); (iv) the respondents' attitudes towards robots through level of agreement (5-point Likert scale) with various statements related to robots' advantages and disadvantages compared to human service employees; and (v) the user experience that robots create in the human-robot interaction.

The experimental and engineering-based research on HRI in the museum sector spans a range of topics. Kuno *et al.* (2007) studied head gestures during explanations of exhibits and concluded that robot head turning may lead to heightened engagement of museum visitors. Yousuf *et al.* (2013) developed a model that describes the constraints and expected behavior when museum guide robots initiate conversation. Rashed *et al.* (2015) observed the behavior of people in an art museum with various levels of interest in the exhibits; they found that it was possible to detect the people who may desire the robot's service from their walking trajectory pattern in the room and developed a method whereby the robot can find such people to offer them guidance concerning their exhibit of interest.

Other authors have applied questionnaires in order to research museum visitors' attitudes. Nomura *et al.* (2007) explored people's attitudes and emotions toward intelligently behaving communication robots after having experienced the robots in the Osaka Science Museum. They used a questionnaire consisting of five statements gauging interest, friendliness, effectiveness, anxiety toward interaction, and anxiety toward social influence. Bickmore *et al.* (2011) evaluated the impact of relational behavior on visitors' engagement with a virtual museum guide named "Tinker".

In the present study, the nine groups of items proposed by De Kervenoael *et al.* (2020) (see appendix) are adapted for application in museums and are used to identify the key dimensions leading to visitors´ intention to use social robots. The items take account of the role of perceived value coupled with empathy and information sharing and their impact on visitors´ intention to use social robots.

Method

Data Collection

The sample was made up of 433 Spaniards who have visited a museum at least once in the last year. Of these, 208 were under 30 years old, and 225 were over 30 years old. The decision to set up two age groups to compare willingness to accept robot use in museums was based on the literature. Not all authors agree on the years that frame the millennial generation. Some, like Strauss and Howe (1991), say millennials were born between 1982 and 2004, while others, like Benckendorff *et al.* (2010), take a narrower view and define the generation as born between 1988 and 2002. Because the age range is a wide one, both museum visit frequency and technology use differ greatly between the maximum age and the minimum age. We therefore decided to split the sample evenly into two age groups, under age 30 and over age 30.

Data on the participants were obtained by launching an e-questionnaire addressed to travelers, who were asked various questions related to their intention to use robots in museums. At the beginning of the questionnaire, a picture of the Pepper robot was shown and the robot's functionality was explained. The collection period was from February to April 2020.

The sampling method was not random. Rather, we used the exponential version of snowball sampling. With this version, each participant invites more individuals to participate. This technique was chosen because it provides ways of communicating with populations that are hard to reach (Johnston and Sabin, 2010), e.g. groups that are difficult to access because of their economic position or geographical location or due to the lack of institutional means of identifying them. In our case, it was difficult, if not impossible, to identify all the actual or potential visitors of museums. Therefore, the population was unknown, and it was impossible to apply a probabilistic sampling method.

The main limitation of snowball sampling is its sensitivity to sampling biases. Sampling biases may occur when the initial group selection is not diverse enough. To reduce this limitation in our research, we created a diverse initial group in terms of age (the sample is evenly balanced between the two age groups) and other variables, such as education, museum visits per year, and income per year.

Instruments

The questionnaire contained nine sections related to the constructs identified by De Kervenoael *et al.* (2020) to analyze the intention of individuals to use robots: perceived utility (PU), perceived ease of use (PEOU), perceived value (PV), intention of use (ITU), service guarantee (SAR), information exchange (ISR), personal commitment (PENG) and tangibles (TG). These items were adapted to museums and rated on a Likert scale from 1 (strongly disagree) to 5 (strongly agree) (see appendix). The modified questionnaire was subjected to a pre-test to check how well it was adapted to museums. The pre-test respondents did not understand one of the original questionnaire's variables concerning the smell of robots ("Robots in a service environment smell better than human employees"). This question was therefore eliminated from the final questionnaire.

Analysis

For the analysis of the results of this study, we conducted an exploratory factor analysis to test the variables' applicability to the case of museums. Factor analyses are very useful for reducing a number of variables to an easily manageable scale (Kinnear and Taylor, 1991) and basically consist of the application of linear combinations of original variables to represent underlying dimensions, constructs, or constructions that summarize or justify an original series of variables under observation (Garrigos *et al.*, 2005).

Once we had identified the factors, we used an ANOVA test to determine whether there were age-related differences between the two groups with regard to the factors related to the intention to use robots in museums. The analyses were performed with SPSS 25.0.

Results

The surveyed visitor sample was 48% people 30 years old or younger and 52% people 31 years old or older. Sixty-two percent were women, and 38%, men. All of them were Spanish. Forty-four percent of those surveyed had visited a museum at least once in the last year, 34.8% had visited a museum two or three times in the last year, and only 14.5% had visited a museum four or more times in the last year. The education level of the sample was high; 58.3% of museum visitors had university degree. In terms of employment status, 30% of participants were students, 60.4% were employed, and 9.6% were unemployed or retired.

One of the aims of the study is to identify the variables that explain the acceptance of robots and adapt them to museums. To facilitate comparison between the two age groups, the high initial number of variables had to be reduced.

In the first phase of the study, we ran an exploratory factor analysis (EFA) to test the variables' adaptation to museums and group the existing items into latent variables. The initial questionnaire contained nine sections with a total of 25 items. We performed an initial promax rotation as a filter, and the results revealed correlations of over 0.32 among factors. This justified carrying out an oblique rotation, as proposed by Tabachnick and Fidell (2001). Items 4, 5, 6, and 23 presented communalities of less than 0.5 and were thus eliminated. The first three eliminated items were related with the "perceived ease of use" construct, and the last belonged to the "tangible" category. This left 21 valid items for our analysis.

Next, as an initial check for independence among the 21 items that explain visitor willingness to accept social robots in museums and age, we applied the chi-square test for independence. We ascertained that all the variables depend on age group save for variable 22, which is related with personal engagement with robots (see table 1).

[Insert Table 1. Chi-square test between willingness to accept social robots in museums and the age]

The EFA yielded a factor structure, based on eigenvalues higher than one, made up of three factors that explained 68.29% of the variance. Bartlett's test of sphericity demonstrated significant correlation between the original variables ($\chi 2$=7484.180, $p<0.001$), while the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was close to 1 (KMO=0.946). The variance explained was 52.73% for the first factor, 9.93% for the second, and 5.62% for the third.

The factors of willingness to accept robots in museums that emerged were interpreted as representing: (1) museum visit experience, (2) empathy, and (3) personal engagement (see table 2).

[Insert Table 2.- Structure matrix (21 items analyzed)]

The first factor, "museum visit experience," is the one containing the largest number of items and therefore the one that best explains robot acceptance in museums. It includes points from TAM related with the degree to which individuals think that use of a given technology will improve performance (Davis, 1989). Moreover, in a service environment, this factor is also related with the idea of quality (De Kervenoael *et al.,* 2020). The factor also includes items from the original "perceived value" construct, which is a multifaceted concept including concepts such as entertainment value and value chain quality. This factor is also related with intention to use social robots in museums (Venkatesh *et al.,* 2003) and information exchange (Admoni and Scassellati, 2017).

The second factor reflects visitors' interest in the robot's understanding and catering to their needs. In other words, it emphasizes "empathy." Empathy is a core element in services and crucial to perceived quality (Parasuranaman and Berry *et al.,* 1991). According to De Kervenoael *et al.* (2020), "Service must appeal to visitors´ emotions because when empathy is observed as emanating from robots, it can be considered to directly serve the intention to use" (De Kervenoael *et al.,* 2020, p. 104042).

Lastly, the third factor reflects the personal engagement of museum visitors with robots by comparing a preference for human or robot service in museums. In the social robot context, De Kervenoael *et al.* (2020) define personal engagement as the visitor's enthusiasm for participating in activities with social robots.

In the second phase of the study, we checked and analyzed age-related differences in robot acceptance. We ran two factor analyses, one for each age group, to check the explanatory factors independently.

Both EFAs yielded a factor structure made up of the same three factors as found before (museum visit experience, empathy and personal engagement). In the case of visitors under 30 years old, the factors explained 65.66% of the variance, while for the group of people over 30, the factors explained 70.851%. Bartlett's test of sphericity demonstrated significant correlation between the original variables in both groups (under 30 years old: $\chi2=3039.081$, $p<0.001$; over 30 years old: $\chi2=4204.483$, $p<0.001$). The KMO measure of sampling adequacy was close to 1 for both groups, too (KMO under 30 years old =0.940; KMO over 30 years old =0.927).

The only difference we found was in connection with item 25 ("Robots in a service environment give a better image than some human employees"). In the EFA of the under-30 group, this item presented a communality of less than .5 (.409) with factor loading in the first factor, "museum visitor experience." In the EFA for the group of visitors over age 30, however, item 25 had a communality of more than .5 (.644), but the factor loading belonged to the third factor, "personal engagement." In view of this inequality, we eliminated item 25 from the model, leaving 20 explanatory items.

We subjected the reduced list to another EFA and again confirmed the three factors explaining robot acceptance in museums: museum visit experience, empathy, and personal engagement (see table 3). After the last refinement of the model, the factors explained 69.45% of the variance, 1.16% better than the initial model. Bartlett's test of sphericity also demonstrated significant correlation among the original variables ($\chi2=7227.059$, $p<0.001$), and the Kaiser-Meyer-Olkin measure was also close to 1 (KMO=0.944).

To contrast the reliability of the new adapted scale, we used Cronbach's alpha, which yielded 0.954 for the first factor, 0.896 for the second factor, and 0.864 for the third. This indicates excellent consistency according to George and Mallery (2003).

[Insert Table 3. Structure matrix (20 items analyzed)]

To determine if the age of Spanish museum visitors influences their acceptance of robots in museums, we used the one-way ANOVA to search for statistically significant differences among the three identified factors.

We found significant differences among all three factors according to age: (1) museum visit experience ($F=32.89$, p-value=.000), (2) empathy ($F=20.851$, p-value=.000), (3) personal engagement ($F=7.178$, p-value=0.008).

The average of the items by factors according to age are presented in figure 1. Visitors age 30 or under scored all variables more highly than did the older group. This means the younger public is more accepting of robot use in museums. Factor 2, "empathy," received the highest scores from both age groups, while factor 3, "personal engagement," was clearly the least important factor for both groups.

[Insert Figure 1. Average of the items by factors according to age]

According to these results, in "museum visitor experience" both age groups believe that the use of robots in museums will be normal in the near future and would offer the vision of a technologically advanced company. However, both age groups have doubts about whether having a robot perform customer services ensures service efficiency. Furthermore, for the younger public, the presence of robots in museums does more to improve their museum-going experience (by enhancing the experience of visiting museums and making the experience more fluid and enjoyable) than it does for the older visitors. The younger millennials also think the use of robots in museums offers more value for money than do the visitors over age 30, who may consider that value for money depends on exhibition quality. Moreover, visitors under 30 agree more strongly than do visitors over 30 that the use of robots in a museum environment is more worthwhile than traditional museum service and delivers a more satisfactory experience. The younger public is readier to use robots in museums in the future, since they feel comfortable interacting with them. All these findings indicate that young millennials could have great potential as a public for museums, if museums would engage in technological innovation.

In the second factor, "empathy," differences appear again between the two age groups. For both groups, the most important thing is for museum robots to understand visitors' specific needs. The under-30 visitors score adaptation to each customer's specific needs and robots' ability to provide individual attention more highly than do the over-30s. These results indicate that young consumers have a greater need for customized services (Sweeney, 2005) while for the older visitors the social abilities of the robot are more important (Heerink et al., 2008).

Lastly, in the "personal engagement" factor, analysis of the differences by age shows that under-30 visitors are more likely than older visitors to think it is easier and feel more comfortable interacting with robots than humans in a museum. Possibly, as shown in previous studies, young people place more value on the use of technology; but, given the low scores, it appears they do not reject the combination of robots with the human factor in services (Ivanov, 2018).

Conclusions and implications

Museums need to increase their customer value and innovativeness so as to ensure their future sustainability (Virto *et al.*, 2017). In recent decades, research about museum innovation has introduced the principles of experience economy (Pine and Gilmor, 1998). Experience, according to Pine and Gilmor (1998) happens when a company engages customers in a way that creates a memorable event. The application of this literature to innovation in museum entities has put the spotlight on improving the client or visitor's experience. To do so, any innovation, be it direct or indirect, must have a satisfactory repercussion on the experience (Camarero *et al.*, 2015). In fact, the search for better experiences has provided the motivation behind a range of innovations in museums and exhibition halls (Camarero *et al.*, 2015), showing that using technology, and more specifically robots, in museums can be a major visitor draw and can contribute to the future viability of a great many museums.

This exploratory study sought to identify the factors that influence the acceptance of social robots in museum environments. The 26 items on the questionnaire used by De Kervenoael *et al.* (2020) were adapted for this purpose. A series of analyses was performed to reduce the initial number of items and cluster them into three main factors: museum visitor experience, empathy, and personal engagement. The results show that individuals under 30 years of age display greater willingness to accept social robots in museums. Although all the individuals surveyed agreed that the use of robots in museums will be normal in the near future, they doubt the efficacy of robot use. Hence, we can confirm that trust is key for the success of robotic applications in service environments (Tussyadiah, 2020). For museum visitors under age 30, the most important factor is empathy, that is, adaptation to the specific needs of each customer, and the possibility of receiving individual attention from robots is more important for younger museumgoers than for the older public (Sweeney, 2005).

Personal engagement is the least important factor for both age groups. However, younger visitors feel more comfortable than older visitors with the idea of interacting with robots instead of humans in a museum. These findings are consistent with previous studies (Ivanov *et al.,* 2018) and the characterization of young people as technology experts and accepting of new technologies. Visitors under 30 years old may be quite supportive of the introduction of social robots in museums. Nevertheless, even the youngest visitors consider human contact in services important.

Practical implications

This research makes a noteworthy contribution to the study of human attitudes towards the introduction of robots in museums. Although some research has been done into robots in museums, past work focuses largely on robot design. Very little work has been done into visitor attitudes towards robots, a topic that is especially important for countries that have yet to bring robots into their museums. Future research should look further into which other demographic and attitudinal factors play the most influential roles in conditioning a person's willingness to accept robotic technologies.

Museums should introduce robot hosts, because robots bring benefits in terms of visitors' experience perception and represent a thoroughly modern approach. In addition, robots can be used as a technological factor to make museums more attractive to the young public and increase attendance by the very young people who in a few years will grow up and become the core museum-going public. It is therefore vital for the future viability of many museums to make today's visits enjoyable for young people.

The benefits of robots are not limited to attracting the young, however. Robots can aid elderly museum visitors who find it difficult to make their way around the building and locate works (Behan and O'Keeffe, 2008). Moreover, in the new post-COVID stage, robots could help monitor health safety in museums and make museums safer to visit by reducing human contact.

Our study is limited by the fact that it is merely exploratory descriptive research, but it does yield important results that should be borne in mind when deciding whether to introduce robots in museums. The sampling technique we used is another limitation, as it may include greater errors than other techniques. Future research in this field should work with confirmatory factor analysis and structural equation modeling to run simulations to determine what variables influence the use of robots in museums and how they operate.

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Appendix. Questionnaire adapted from De Kervenoael et al. (2020) to museums

Perceived Utility (PU)
1ENHANCE. Robots would be useful to enhance the experience in a museum.
2ENJOYABLE. The use of robot technology would make the experience of visiting a museum more enjoyable.
3FLUID. The use of robots in a museum would make the visit more fluid.

Perceived Ease of Use (PEOU)
4SKILLFUL. In my opinion, it is easy to become skillful at using robots in a service environment.
5UNDERSTAND_USE. In my opinion, it is getting easier to understand how to use robots in a service environment.
6RESTRICT. In my opinion, robot technology restricts the experience in a service environment.

Perceived value (PV)
7WORTHWHILE. Compared to a traditional service, the use of robots in a museum would be worthwhile.
8SATISFACTION. The use of robots in a museum would offer a satisfying experience.
9VALUEFORMONEY. Compared to the cost of the service I have to pay, the use of robots in a museum would offer excellent value for money.

Intention of use (ITU)
10USE. Given the opportunity, I'll use robots in a museum.
11NORMAL. I believe that the use of robots in the service sector will be normal in the near future.
12FUTURE. I intend to use robots more and more in the future if I can.

Service Guarantee (SAR)
13EFFICIENCY. Having a robot perform customer services ensures service efficiency.
14CATER. Robots in a service environment like a museum are programmed to cater to visitors´ specific needs

Empathy (EMP)
15UNDERSTAND_NEED. Robots in a service environment usually understand the specific needs of the visitors.
16INDIVIDUAL_ATTENTION. Robots in a service environment like a museum usually give customers individual attention.
17AVAILABLE. Robots in a museum are available whenever it´s convenient for customers.

Information Exchange (ISR)
18SHARING_EASY. In my opinion, sharing information with robots in a museum would be easy.
19SHARING_UNDERSTAND. In my opinion, I could easily understand the information shared by robots in a museum.

Personal Engagement (PENG)
20COMFORTABLE_WITH. In my opinion, I would feel comfortable interacting with robots in a museum.

21MORE COMFORTABLE_HUMAN. In my opinion, I would feel more comfortable interacting with robots than humans in a museum.
22INTERACT_EASIER. In my opinion, it would be easier to interact with robots than humans in a museum.

Tangibles (TG)
23VISUAL_LANDSCAPE. Robots in a service environment are part of the visual landscape.
24TECH_VISION. Robots in a service environment would offer the vision of a technologically advanced company.
25BETTER_IMAGE. Robots in a service environment give a better image than some human employees.

Willingness to accept social robots in museums according to age: An exploratory study of Spanish visitors

TABLES

Table 1. Chi-square test between willingness to accept social robots in museums and the age

Items adapted to museums	*Value*	*df*	*Sig.*
1ENHANCE	*29.785*	*4*	*.000(***)*
2ENJOYABLE	*18.870*	*4*	*.001(***)*
3FLUID	*17.524*	*4*	*.002(***)*
7WORTHWHILE	*22.076*	*4*	*.000(***)*
8SATISFACTION	*37.074*	*4*	*.000(***)*
9VALUEFORMONEY	*29.248*	*4*	*.000(***)*
10USE	*33.001*	*4*	*.000(***)*
11NORMAL	*25.182*	*4*	*.000(***)*
12FUTURE	*24.302*	*4*	*.000(***)*
13EFFICIENCY	*27.279*	*4*	*.000(***)*
14CATER	*31.565*	*4*	*.000(***)*
15UNDERSTAND_NEED	*29.050*	*4*	*.000(***)*
16INDIVIDUAL_ATTENTION	*19.337*	*4*	*.001(***)*
17CONVENIENT	*18.520*	*4*	*.001(***)*
18SHARING_EASY	*16.772*	*4*	*.002(***)*
19SHARING_UNDERSTAND	*26.109*	*4*	*.000(***)*
20COMFORTABLE_WITH	*21.859*	*4*	*.000(***)*
21MORE COMFORTABLE_HUMAN	*16.269*	*4*	*.003(***)*
22INTERACT_EASIER	*6.709*	*4*	*.152*
24TECH_VISION	*30.640*	*4*	*.000(***)*
25BETTER_IMAGE	*22.604*	*4*	*.000(***)*

(***) p-value<1%, the hypothesis of independence is rejected

Table 2.- Structure matrix (21 items analyzed)

Items adapted to museums	**Components**		
	1	2	3
1ENHACE	*,840*		
2EJOYABLE	*,834*		
3FLUID	*,816*		
7WORTHWHILE	*,810*		
8SATISFACTION	*,893*		
9VALUEFORMONEY	*,799*		
10USE	*,866*		
11NORMAL	*,672*		

12FUTURE	*,796*		
13EFFICIENCY	*,741*		
18SHARING_EASY	*,744*		
19SHARING_UNDERSTAND	*,760*		
20CONFORTABLE_WITH	*,803*		
24TECH_VISION	*,648*		
14CATER		*,825*	
15UNDERSTAND_NEED		*,901*	
16INDIVIDUAL_ATTENTION		*,893*	
17AVAILABLE		*,840*	
22INTERACT_EASIER			*,896*
21MORE CONFORTABLE_HUMAN			*,900*
25BETTER_IMAGE			*,720*

Table 3. Structure matrix (20 items analyzed)

Items adapted to museums	Components		
	1	2	3
1ENHANCE	*.838*		
2ENJOYABLE	*.831*		
3FLUID	*.815*		
7WORTHWHILE	*.809*		
8SATISFACTION	*.892*		
9VALUEFORMONEY	*.800*		
10USE	*.865*		
11NORMAL	*.673*		
12FUTURE	*.797*		
13EFFICIENCY	*.743*		
18SHARING_EASY	*.746*		
19SHARING_UNDERSTAND	*.762*		
20COMFORTABLE_WITH	*.805*		
24TECH_VISION	*.653*		
14CATER		*.826*	
15UNDERSTAND_NEED		*.902*	
16INDIVIDUAL_ATTENTION		*.897*	
17AVAILABLE		*.840*	
22INTERACT_EASIER			*.904*
21MORE COMFORTABLE_HUMAN			*.927*