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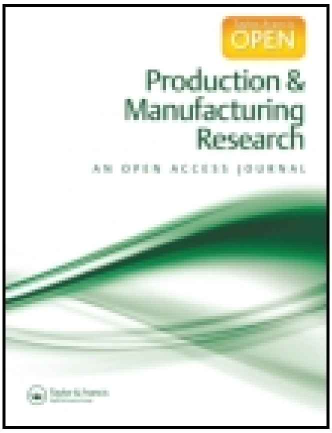

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Evaluating the use of mobile collaborative augmented reality within field service networks: the case of Océ Italia - Canon Group

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The adoption of Augmented Reality (AR) technologies can make the provision of field services to industrial equipment more effective. In these situations, the cost of deploying skilled technicians in geographically dispersed locations must be accurately traded off with the risks of not respecting the service level agreements with the customers. This paper, through the case study of a leading OEM in the production printing industry, presents the challenges that have to be faced in order to favour the adoption of a particular kind of AR named Mobile Collaborative Augmented Reality (MCAR). In particular, this study uses both qualitative and quantitative research. Firstly, a demonstration to show how MCAR can support field service was settled in order to achieve information about the use experience of the people involved. Then, the entire field force of Océ Italia – Canon Group was surveyed in order to investigate quantitatively the technicians' perceptions about the usefulness and ease of use of MCAR, as well as their intentions to use this technology.

Keywords: field services; mobile collaborative augmented reality; technology acceptance model; case study research

1. Introduction

This paper presents the results of an evaluation study of user acceptance concerning the adoption of Augmented Reality (AR) to support the delivery of field services on installed products. These services include both the maintenance activities to ensure timely recovery of the product operable status, altered as a consequence of faults, deteriorations, etc., as well as those that ensure the product availability. Examples of the first are fix & repair activities, whereas of the second are diagnosis, inspection, tele-control and preventive maintenance. The provision of those services is proven to be critical for manufacturing companies that are commuting to service-oriented business (Grönroos, 2008; Mathieu, 2001a, 2001b; Meier, Roy, & Seliger, 2010; Schmenner, 2009). To comply with contractual service level agreements (SLAs) and be profitable at the same time, in fact, a certain amount of ambidexterity is requested. The importance of an efficient service network of different resources as field-technicians, spare parts, tools, vehicles, etc., becomes even more critical with the increase of the number of products that are installed and operated in customer facilities that are globally distributed. Irrespective

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of who plays the role of the service provider (i.e., directly the OEM via its service divisions rather than global or local partners), relevant knowledge about product technology is requested in order to deliver, along the product′s life cycle, the demandable services. Most of the mentioned knowledge pertains to product specialists and, therefore, usually resides in the manufacturer's research and development centres, where it should be properly collected, accumulated, shared and distributed to field workers whenever requested (Corso, Martini, Pellegrini, Massa, & Testa, 2006). However, the more the installed base (IB) (Ala-Risku, 2009) is widespread, the more to be effective in product knowledge management is a challenging issue.

In a situation like this, information and communication technologies (ICTs) play a major role to support both communication and information management in service networks (Greenough & Grubic, 2010; Kowalkowski, Kindström, & Gebauer, 2013; Shugan, 2004). As pointed out by Aberdeen Group (Dutta, 2012), field technicians are generally equipped with laptops or tablet PCs as well as with mobile phones. The first are used to run diagnostic routines and field service applications and to access technical documents. The second, instead, are used to interact with remote colleagues and ask for support, if necessary. However, these devices have some limitations, such as: (i) their interfaces are not intuitive for information retrieval, (ii) they scarcely support hands-free movements and (iii) some misunderstandings may occur during voice communication, as people that interact do not have the same view of the situation.

In this sense, AR is an emerging technology (Fenn & LeHong, 2011) that could overcome the above-mentioned limitations. Basically, through AR, the real world vision is supplemented (i.e. augmented) with real-time, interactive, computer-generated objects that coexist in the same space as the real scene (Azuma et al., 2001). Up to now, the scientific literature identifies maintenance service as one of the growing application areas for AR (Nee, Ong, Chryssolouris, & Mourtzis, 2012; van Krevelen & Poelman, 2010). However, since AR is still at its pioneering stage, literature that investigates in depth its potential applications in real scenarios is very scarce. Most of the existing papers are, in fact, focused on discussing technology advances and developing state-of-the-art prototypes (Zhou, Duh, & Billinghurst, 2008). The few works that address the impact of AR technology usually focus on usability of devices and on the design of human–computer interfaces (Bowman, Gabbard, & Hix, 2002; Swan & Gabbard, 2005). In detail, these authors investigate issues such as the ways the users control the interfaces, the efficacy in error prevention and information retrieval, and the design of the aesthetic and ergonomics. However, since the users' attitudes can influence, to a large extent, whether or not a system will be used in a given context (Nilsson, 2008), this study focuses on individual perceptions and expectations to evaluate the acceptance of AR in a field service organization. In particular, this paper deals with the so-called Mobile Collaborative Augmented Reality (MCAR) technology that can be suited to support the interactions between a field technician and a remote expert, as it enables hands-free operations and symmetrical communication between multiple users.

With this respect, the assessment of users' acceptance when adopting MCAR technology in field services remains unexplored. So, this work intends to fill these gaps, presenting the case study of a company that provides contractual services such as routine maintenance, fix & repair, etc., to the customers of its production printers. To address the affection of technicians towards MCAR, the study resorted to: (1) a demonstration of the features of a real MCAR system, that was specifically planned and executed in a real setting, thus involving some potential users; and (2) a survey that was administered to the entire field force, in order to assess usefulness and ease-of-use of

MCAR. As a result, technical and managerial issues that can prevent the adoption of this kind of technology were identified from the interviews performed after the demonstration to participants. In addition, with the survey, the intentions to use MCAR by field force were quantitatively investigated. For this latter aim, we recurred to a questionnaire that was designed in accordance to the theory of Technology Acceptance Model (TAM) (Davis, Bagozzi, & Warshaw, 1989; Davis & Venkatesh, 2004).

The remainder of the paper is organized as follows. Section 2 describes the potentials of AR technologies in the provision of field services, as well as how acceptance models are used to address these issues. Then, Section 3 shows the research methodology of this study. In Section 4, the evaluation of MCAR is presented from both qualitative and quantitative point of view. Then, the paper concludes presenting the avenues for further research in Section 5.

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2. Review of the literature

2.1. The adoption of AR in field service networks

AR is considered a breakthrough technology to improve the way field services are delivered (Fenn & LeHong, 2011; Porcelli, Rapaccini, Espíndola, & Pereira, 2013). In fact, AR can enable real-time display of lengthy textual data, symbols, graphics, etc. that can be superimposed to the real images (Henderson & Feiner, 2007). Therefore, AR devices are helpful in case technicians need to receive remote support (e.g. information about how a given maintenance or repair task should be accomplished), while keeping their hands free and their eyes fixed on specific points of the serviced equipment. In particular, an AR system includes: (i) a computer system to run the AR application; (ii) a digital camera to capture the real scene; (iii) a tracking system to track the position and movements of users and objects and to link the virtual augmentation with a specific position in the scene; (iv) a head-mounted or hand-held display to see the real scene augmented; and (v) a data acquisition system such as gloves, tablets and PDAs to interact with the AR application. Further details can be found in Zhou et al. (2008) and van Krevelen and Poelman (2010).

According to Porcelli et al. (2013), field services can be supported by two kinds of mobile AR systems: automatic/single-user and collaborative/multi user-systems. The first and most common AR systems are based on software agents that automatically guide technicians in performing their tasks. In this case, work procedures are preventively converted into virtual models through content generation system (Espíndola et al., 2013) and then provided to the technicians. Through specific tracking systems, the viewed scene and the user movements are recognized, while virtual signs, texts and augmentations are superimposed in the right position on a see-through display. Examples of such technologies are presented by Platonov, Heibel, Meier, and Grollmann (2006), Henderson and Feiner (2007), De Crescenzio et al. (2011). Conversely, a MCAR enables remote collaboration among multiple users that, by means of mobile devices, interact and execute AR applications (Billinghurst & Thomas, 2011). As suggested by Porcelli et al. (2013), MCAR is particularly suited in case of diagnostic and troubleshooting activities as well as complex fix & repair interventions. In such situations, field technicians may be willing to receive support by experts (e.g. product and technology specialists) that are remotely located, since they could perceive they are not prepared to accomplish the required tasks as well as to handle unexpected events. Of course, this mostly occurs when dealing with complex tasks as well as when the decisions to be taken are critical for recovering the continuity of the customer's business. Since MCAR enables field users to share the images they are seeing in real time to the remote expert, this latter can guide them step-by-step, giving aids through voice, gestures, and superimposed virtual objects. Examples of MCAR can be found in Bottecchia, Cieutat, Merlo, and Jessel (2009), Alem, Tecchia, and Huang (2011), Azpiazu et al. (2011).

In the next section, the literature on the user acceptance of AR applications is reviewed, in order to point out the most relevant findings with respect to the aims of the study.

2.2. The user's acceptance of AR in field service

In MIS literature (Davis, 1989; DeLone & McLean, 1992), the intention to use a technology by its potential or actual users is considered a well-accepted proxy of the technology's potential or actual impact on the organization. Therefore, it is crucial to assess these intentions on the basis of attitudes and perceptions of individuals. Broadly speaking, the theoretical body derived by utilization-related models argues that the utilization of a technology is the result of the user's belief about, and affect towards it (Davis, 1989; Venkatesh, Morris, Davis, & Davis, 2003). In particular, two beliefs, i.e. perceived usefulness (PU) and perceived ease of use (PEOU), help to establish the attitudes (A) of individuals towards a technology, their (behavioural) intention to use it (BI) and, thus, the resulting actual use (AU). These constructs and the corresponding relationships are the fundamentals of the well-known Technology Acceptance Model (TAM), as proposed by Davis et al. (1989) in their seminal work. Since its original development, TAM has been extended several times. For instance, some authors suggest a direct influence of PU and PEOU on the intention to use (Agarwal & Prasad, 1998; Gefen & Keil, 1998; Venkatesh & Davis, 1996), whereas some others suggest to integrate TAM with new constructs and moderators (Al-Gahtani, 2011; Burton-Jones & Hubona, 2006; Davis et al., 1989; Venkatesh & Davis, 2000). Finally, some papers propose to merge different theories, such in the case of the Unified Theory of Acceptance and Usage of Technology (Venkatesh et al. (2003).

Despite the literature that deals with the user's acceptance of AR is rather scarce, some findings can be remarked. Firstly, despite AR has been appointed as a promising technology for both business and private life applications such as learning, education, leisure and entertainment (Olsson & Salo, 2011), technology acceptance is, up to now, assessed mostly in leisure and entertainment applications. Secondly, TAM is the theory preferred by scholars, but its application differs with respect to the constructs that are considered in the measurement model. In fact, some authors include context-specific factors such as perceived enjoyment (Balog & Pribeanu, 2010; Haugstvedt & Krogstie, 2012; Pribeanu, 2011) rather than perceived innovativeness (Rasimah, Zaman, & Ahmad, 2011). In addition, the methodologies that are used for analysing data vary to a great extent. Some authors, in fact, examine their data only qualitatively (Nilsson & Johansson, 2007) because of a limited data sample, whereas some others carry out statistical analyses such as correlation/multiple-regression (Rasimah et al., 2011) as well as structural equation modelling (SEM) (Arvanitis et al., 2011; Balog & Pribeanu, 2010; Haugstvedt & Krogstie, 2012). Finally, most of the studies refer to a pre-implementation stage (Davis & Venkatesh, 2004), in which end users are totally unfamiliar with AR. Hence, prior to survey their perceptions, they are given the possibility to either test the technology, directly using prototypes (Arvanitis et al., 2011; Balog & Pribeanu, 2010) or to receive thorough explanations of its features by means of videos and/or interactive

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presentations (Haugstvedt & Krogstie, 2012). For these reasons, 'intention to use' is assessed as the dependent variable in place of 'actual use' construct that, in fact, is not included in the reviewed papers.

Summing up, the existent literature on user acceptance of AR does not focus on MCAR technology neither on its adoption in the provision of industrial maintenance and field services. Therefore, this study can contribute to add knowledge to this topic. In the next section, the research methodology is presented.

3. Research methodology

Since research upon managerial impacts and user acceptance of MCAR technology is still in its infancy, the underlying concepts still need to be explored and clarified. Thus, this study adopted a qualitative case-based research that has proven to be particularly adequate in the early stage of theory building (Meredith, 1993; Voss, Tsikriktsis, & Frohlich, 2002). In particular, during the first six months of 2012 an in-depth single case study in Océ Italia – Canon Group was carried out.

3.1. Case study selection

Recently, Océ has been taken over by Canon, and now it is part of the Canon Group. However, at the time of the study, it was a large multinational OEM of wide format printers (for technical documentation and display graphics) and production printers (for marketing service bureaus and graphic arts). The analysis focused on the Italian subsidiary of this company (i.e. Océ Italia – Canon Group). This company was selected since: (i) it provided contractual services, such as routine maintenance, spare parts, consumables, repairs and upgrades, to the owners/operators of its professional products; (ii) a substantial part of revenues (around 30%) streamed from service contracts; (iii) services were delivered by a direct work force, according to specific SLAs; (iv) the service network was sufficiently large to consider field technicians as dispersed workers (Corso et al., 2006); (v) the service director was interested in investigating how collaboration among field technicians and remote experts could be improved by means of AR and mobile technologies; and (vi) the authors were allowed to access the company's data as well as to interview the field force.

3.2. Case description

At the time of the study, Océ Italia – Canon Group, that was responsible for selling products and services on the Italian market, had more than 30 service centres spread over Italy, mostly located near customers' premises. In the company's portfolio, production printers were pointed out as the most complex and critical products to be serviced. Thus, the latest model of continuous feed production printer was selected, in order to address the potential applications of MCAR in those cases in which the effective provision of field services can be largely critical for the continuity of the customer's business. In fact, since this equipment can reach a speed higher than 1000 duplex A4 printed pages per minute, they are the core of the production process of Trans Promo and Direct Mailing business. To manage this huge printing data flow, besides mechanical and electrical parts, these machines are equipped with sophisticated controllers and dedicated software. Therefore, their maintenance and restoration require capabilities and tools that

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cannot be provided for free. Hence, these printers are sold in conjunction with different types of multiyear service contracts. In the most common situation, services such as installation, preventive maintenance, replacement of defective/broken spares, remote support and firmware upgrade are provided by the service network against a fixed-rate fee. However, the required service performance is dictated by SLAs that may specify response or recovery times, as well as the yearly availability of equipment that has to be assured. In case the expected performances are not respected, some penalties may incur. Hence, to make more profits and achieve customers' satisfaction, the service network is in charge of delivering effective and efficient field services, in the shortest time. This is not straightforward, due to the following reasons. Firstly, as innovation cycles become shorter, new printers as well as hardware, firmware and software updates are continuously released to the market. Hence, field force needs to be systematically trained and this is expensive and complicated, since technicians are geographically dispersed. Secondly, unexpected events and/or unknown situations frequently occur in the field. Hence, field force needs to constantly receive support from remote experts. Irrespective whether the ultimate goal is to either train technicians from remote centres or support remotely the field intervention, in many occasions, the field force is requested to communicate with remote experts – such as product specialists – that are located in customer support centres. To this regard, field technicians are commonly equipped with mobile phones and laptop PCs. These latter can be used to connect to the printer, run diagnostic checks, retrieve operating status and fault history, as well as to access technical documentation, including users manuals and technical procedures. In case a field issue cannot be solved by the field technician in isolation, remote support must be requested. The first attempt is, thus, to use the mobile phone, call the product specialist, explain the current situation and ask for suggestions. If the problem cannot be solved yet, the product specialist establishes a remote connection to the machine and runs some troubleshooting procedures. If a solution is not found, a technical visit by the product specialist has to be scheduled within the next days.

From the above considerations follows that the Océ Italia – Canon Group field service network is adopting a typical multi-skills structure, where issues are escalated from bottom to upper levels, in order to engage more skilled resources if necessary. Given the intense collaboration among the network levels, the Océ Italia – Canon Group service director was very committed in evaluating a technology that, even if at a pioneering stage, could improve the information exchange. This is clearly pointed out by this passage from the interview:

> We have to face different degrees of criticality and complexity of field interventions, thus we designed our service network with different levels of competence in order to adequately support the field force. The introduction of ICT that could improve the way we deliver services is thus an interesting opportunity.

3.3. MCAR selection

The MCAR system was provided by a start-up company whose name, for confidentiality reason, has been withheld. The system matched the following criteria: (i) it allows hands-free operations and video/audio communication between remote users; (ii) it does not require to place markers in the customer's facility; (iii) it can be easily set up in any context; and lastly, (iv) a functioning prototype can be used for the demonstration (see Figure 1).

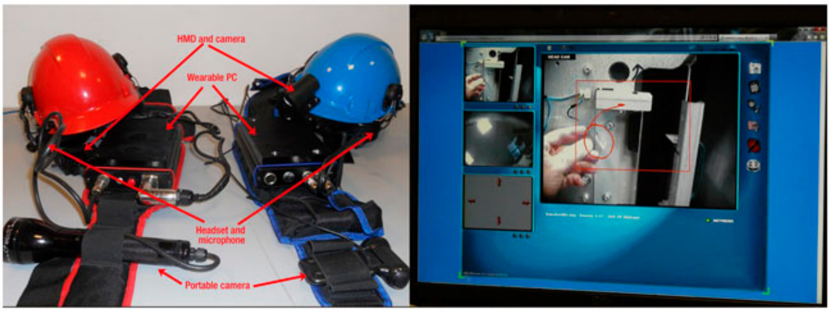

Figure 1. Selected MCAR system for the case study.

The selected system includes a mini PC and a portable camera which is tied at the technician's waist. The technician also wears a head-mounted display that can be either optical or video see-through, as well as a camera and a headset that are both mounted on the helmet. The product specialist, instead, is remotely connected via a desktop/laptop computer, where the software for AR runs. This way, the product specialist receives audio/video streams from the cameras and uses a microphone to talk to the field operators, giving them visual instructions (e.g. text, arrows, circles and 3D images) as well as voice commands. Communication is supported by different networks such as Wi-Fi, LAN, cellular or satellite. For scene tracking – to determine the user's position and superimpose virtual information in the right point of the screen – the software employs an efficient recognition algorithm, which is based on natural features, and thus, does not require the use of markers neither on the equipment nor on the customer environment. Lastly, documents, drawings, manuals, etc. can be uploaded in the system by the product specialist and sent to the technicians in real time, thus making this system really plug and play.

3.4. Research protocol

In the proposed case study, both quantitative as well as qualitative methods were adopted. To evaluate different usage experiences of MCAR technology, a demonstration in a real environment/scenario was arranged. Firstly, we asked the service director for selecting one of their customers to host the usage demonstration at its factory, making available some printers to simulate the servicing activities. A company that prints massive volumes of transaction-related documents, such as statements, invoices or bills, using the latest models of production printers manufactured and serviced by Océ Italia – Canon Group, was chosen. After having explained the purposes of our study, the manager agreed to stop for a few hours one of its machines to allow our demonstration to take place. The only restriction was that the demonstration should not occur at the end of a quarter, when millions of bank statements have to be printed and sent to the account holders. Secondly, a non-disclosure agreement of reserved and confidential information was prepared and signed by the involved parties, i.e. our laboratory, Océ Italia – Canon Group, the selected customer and the MCAR provider. Then, the demonstration programme was defined in accordance with the service director of Océ Italia – Canon Group. In particular, a couple of technicians and a product specialist that were appointed to be representative of the field force were selected to take part in the demonstration.

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After being equipped with the technology, they were asked to, respectively, execute and remotely support certain service activities. Lastly, they were interviewed recurring to a semi-structured questionnaire that was previously prepared by the researchers. In addition, the authors interviewed the service director – who assisted to the event without interfering – in order to obtain data triangulation as well as internal consistency (Yin, 1994). This allowed us to achieve new insights into the opinions of the interested people from multiple points of view. A short video of this experience was produced to explain how MCAR could support the execution of field services in the Océ Italia – Canon Group assistance network. This was crucial for the second stage of this research. In fact, the field force was asked to watch this video and then to answer the questionnaire. This latter was prepared, based on the theory of Technology Acceptance Model, to address the intention to use MCAR in field services against a larger sample.

3.5. Demonstration and interview settings

The purpose of the demonstration is to achieve information about the use experience of the people involved that, therefore, act as informants. Their roles and company positions are pointed out in Table 1. In order to let both the technicians and the remote specialist experiment the MCAR system and get aware of its main features, the real conditions of different service scenarios were simulated.

Then, in order to evaluate the learnability and ease of use of the MCAR system from a broader perspective, only the technician identified as Informant C received a 2-h training session. In this way, the differences in the PEOU of the technology could be observed. In particular, detailed instructions were given on how to wear the personal devices, how to use the see-through display and to visualize the contents superimposed to the real environment, etc. Lastly, two scenarios related to the use of MCAR to support the execution of field service activities were planned and executed. These consisted, firstly, in running a troubleshooting procedure to discover the causes of a simulated malfunctioning. Then, the field operator had to identify, among several components, the one that caused the fault (e.g. a disconnected switch) and, lastly, to execute the maintenance activity. Demonstration was repeated twice, with *Informant C* and *D*, both being remotely supported by *Informant B*. Actually, he was located in a room next to the job shop in order to let the researchers observe his behaviour at the same time. To make them comfortable, the people involved were previously assured that the observers were not evaluating their individual performance. At the end of the experiment, all participants were requested to take part in a face-to-face interview. In particular, they were asked to report their overall impression of the MCAR use, the difficulties they had, the positive

Table 1. People from Océ Italia – Canon Group involved in the case study.

Informant	Company position	Role played in the demonstration
A	Service director	Responsible of managing and coordinating the team of people involved, as well as to handle the relationships with the customer that hosted the demonstration
B	Product specialist	Remote expert, responsible to guide the field technicians in executing the intervention, by means of the MCAR system
C and D	Field technicians	Workforce, responsible to directly execute the field intervention supported by the remote expert through MCAR

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aspects, what they would change and, lastly, the issues they believe could prevent the adoption of MCAR technologies in supporting their field operations. Each interview lasted around one hour, were tape-recorded, then transcribed and sent to the *Informants* for validation.

3.6. Survey design and dissemination

To obtain a quantitative evaluation of the acceptance level of MCAR technologies by technicians, a questionnaire was developed in line with the extant literature on TAM (see Section 2.2), and the entire work force of the Océ Italia – Canon Group network was surveyed. This questionnaire was structured in two parts. The first was purposed to collect general information such as gender, age and work experience of respondents. The second, instead, was designed to reflect the items that are generally used to measure the perceptions of respondents about their attitude to, and affection towards, a technology. In detail, it was assumed that the behavioural intention to use MCAR (BI) should be jointly determined by: (i) the PEOU, which is the degree to which the users expect the technology to be free of effort; and, (ii) the PU, which is the extent that the users expect an increase in their job performance (in terms of effectiveness, productivity as well as efficiency) as a consequence of the use of the technology. In addition, it was also assumed a direct influence of PEOU on PU, as suggested by several authors (Davis & Venkatesh, 2004; Venkatesh & Davis, 1996). However, since MCAR was not adopted at the time of the experiment by the Océ Italia – Canon Group service network and therefore its technicians were not familiar with it, some changes to the traditional approach had to be made. Firstly, since the construct ‘actual usage’ could not be investigated, we focused on ‘intention to use’ as the dependent variable. Then, despite the items that measured the TAM constructs were based on the works from Wu, Cheng, Yen, and Huang (2011), Dishaw and Strong (1999), Venkatesh and Bala (2008), Al-Gahtani (2011), they were rephrased in a hypothetical way since respondents do not have direct experience with MCAR. Participants were asked to express their agreement to each of the statements shown in Table 2, according to a five-point Likert scale.

Table 2. Question items used in the study.

Construct	Item	Measure
PU	PU_1	I think that the usage of MCAR system would improve my job performance, enabling the communication with the product specialist in order to analyse and solve the problem
	PU_2	Using MCAR system would enable me to accomplish tasks more quickly
	PU_3	Using MCAR system would enhance my effectiveness in my field service tasks
	PU_4	I think that MCAR system would simplify my job
	PU_5	Overall, I think that MCAR system would be useful in my job
PEOU	PEOU_1	Learn how to use MCAR system would be easy and fast for me
	PEOU_2	I think that using MCAR system in real settings would be easy for me
	PEOU_3	I think that using MCAR system in my job would require a lot of mental efforts
BI	BI_1	Assuming MCAR system would be available on my job, I predict that I will use it every time I need to ask for support
	BI_2	I would like to have REAL system as an available equipment for my field service tasks

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We prepared a cover letter and an e-mail that informed the respondents about the purpose of the research and pointed out the features of MCAR technology. To this latter concern, we included in the e-mail the links to access to: (i) a short presentation of the features of MCAR technology; (ii) a video clip – produced during the demonstration – illustrating the applications of MCAR to field service, and; and (iii) the survey to be answered. To obtain a higher response rate, the request to fill the survey was directly forwarded to the technicians by their service director (*Informant A*). To make respondents aware of MCAR technology, they were explicitly asked to watch the presentation and the video clip prior to filling the survey.

4. Evaluation of the acceptance of MCAR in the case study

4.1. Findings from the demonstration

Technicians involved in the demonstration gave a positive evaluation about the use of the MCAR system. As *Informant B*, *C* and *D* agreed, the device was found to be *easy to use, simple and user-friendly*. The system was suggested to be particularly effective in supporting field interventions, in case uncertainty is a big deal or the situations are not familiar to the field technicians. This is remarked by the following passage from *Informant C*'s interview: *When there is a strong need for collaboration, as for servicing new products, these devices are certainly useful*. Moreover, a substantial improvement of the communication between the remote expert and the field technician was recognized as the bidirectional exchange of visual information was proven to lower misunderstandings. *I cannot deny my enthusiasm for the system that, if properly implemented can give good results, greatly improving also my daily activities* stated *Informant B*. As *Informant B* agreed, in case field technicians would use MCAR, the amount of field interventions by product specialists – third-level support – could be greatly reduced.

On the other hand, the interviewees pointed out some issues that, in their opinions, should be overcome before MCAR could be adopted for field services. Some issues relate to a not adequate ergonomics of the devices. For instance, both respondents B and C complained that the size and the weight of the head-mounted display should be reduced to avoid stress for its users in case of prolonged use. As also confirmed by some authors (van Krevelen & Poelman, 2010; Zhou et al., 2008), these kinds of improvements are crucial for state-of-the-art devices, prior to introducing them in industries. Despite technicians found that *using* a head-mounted display *was intuitive and easy*, they actually suggested that some additional resting time could be required as a consequence of the eye's strain due to the continuous change of focus of the see-through displays. In addition, the way the different equipment is worn should match any health and safety requirements. For instance, to hold up the camera, the display and the headset, wearing a helmet is adequate in case workers are anyway obliged to wear helmets due to safety requirements. Some other limitations identified in the experiment can be easily overcome with technology. For instance, the cable that connects the display with the mini PC and that restricts the mobility of the user could be replaced by a wireless connection. Finally, the portable camera was extremely useful to access tight areas and send pictures and video streams of hidden objects. Nevertheless, some additional lights would allow a clearer view of the most shaded objects. In addition, this video stream could be enhanced as well, through the superimposition of virtual objects by the remote expert.

Another critical issue that was pointed out is related with the efficiency and security in transferring data and communication between remote users. With respect to the first aspect, *Informant B* believed that *good connection and transfer rates are the basis of a successful AR experience*. Hence, the choice of the telecommunication infrastructure – Wi-Fi, cellular or satellite – plays a crucial role. Moreover, the transfer of data has to be protected by means of secure protocols, since customers would never allow unencrypted data to be accessed and transmitted outside their facilities. This latter issue was remarked also by *Informant B* that, in a passage of his interview, highlighted the *problem to connect the machine with the external world*.

4.2. Findings from the survey

The entire field service network of Océ Italia – Canon Group, counting 92 technicians, was surveyed. Apart from those participating in the demonstration, none of the respondents were familiar with either MCAR or AR. After excluding those questionnaires with invalid or left blank answers, we counted 65 respondents, thus having a response rate of 70.6%. All respondents were male, 68% aged between 40 and 50 years old and, on average, they showed a good work experience: 50% of them declared that they had more than 25 years of experience in delivering field services to printing equipment. Analyses have been performed using SPSS 19 and spreadsheets. In the following, the major findings are presented.

4.2.1. Constructs reliability

The scales that are used to measure each construct (i.e. PU, PEOU and BI, acronyms are explained in section 3.6) were examined for internal consistency, by subjecting it to Cronbach's alpha test. Both PU and BI showed a Cronbach's alpha (0.923 and 0.939, respectively) greater than the standard threshold value of 0.70 (Nunnally, 1978). PEOU, instead, showed a lower Cronbach's alpha value (i.e. 0.597), due to the inclusion of item PEOU_3. This latter, in fact, was expressed with a reverse scale in comparison to the others that measure PEOU. Probably, the questionnaire turned out to be not enough clear in specifying that respondents have to follow a reverse scale in order to provide answer to this question. Hence, a large number of answers were found not being correlated with the other items of PEOU. However, removing PEOU_3 and repeating the test, the Cronbach's alpha increases to 0.878, which is an acceptable value. Hence, a questionnaire including nine items was proven to be reliable.

4.2.2. Evaluation of MCAR

The result of the descriptive analysis is shown in Table 3 and in Figure 2.

In sum, it turns out that the PU of MCAR is satisfying more than 3 out of 5 technicians. In particular, they perceive that MCAR would help them in being more effective in their work; for instance, when they have to find the cause of malfunctioning. In fact, 73% of respondents agree with PU_1 and 74% with PU_3 (see Figure 2). Conversely, 36 and 33% of respondents, respectively, do not think that MCAR can considerably speed up field interventions (i.e. PU_2) and simplify their work operations (PU_4). Despite the overall evaluation of usefulness is good (3.34 out of 5), other sources of usefulness that have not been explicitly investigated might exist, since this value is higher than other PU measures.

With respect to the PEOU constructs (see Figure 3), few respondents (14%) declared that MCAR could be hard to learn (PEOU_1), while 69% agree that MCAR could be

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Table 3. Descriptive statistics (1 = strongly disagree to 5 = strongly agree).

Construct	Item	*N*	Min	Max	Mean	SD
PU	PU_1	65	1	5	3.11	1.13
	PU_2	65	1	5	3.00	1.19
	PU_3	65	1	5	3.11	1.08
	PU_4	65	1	5	3.00	1.13
	PU_5	65	1	5	3.34	1.07
PEOU	PEOU_1	65	1	5	3.49	1.06
	PEOU_2	65	1	5	3.12	1.05
BI	BI_1	65	1	5	3.28	1.15
	BI_2	65	1	5	3.27	1.18

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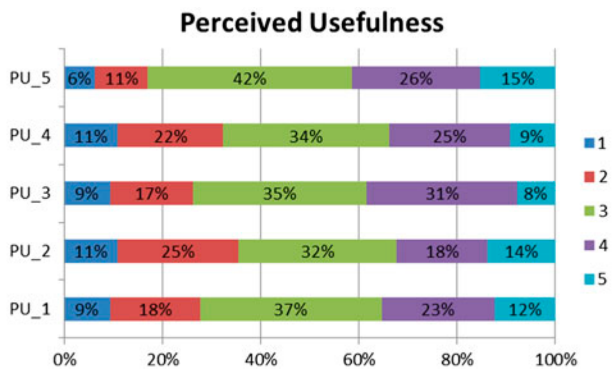

Figure 2. Results for perceive usefulness (1 = strongly disagree to 5 = strongly agree).

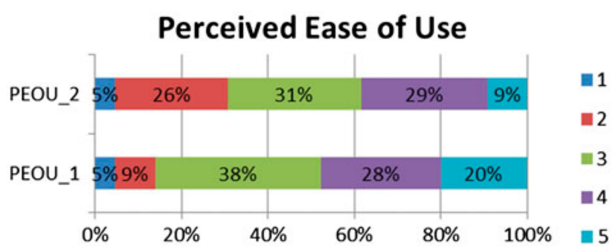

Figure 3. Results for perceive ease of use (1 = strongly disagree to 5 = strongly agree).

easy to use (PEOU_2). Hence, we conclude that MCAR is considered both easy to learn and to use. However, 38 and 31% (respectively for PEOU_1 and PEOU_2) of respondents answered the central value of the scale, suggesting that this construct is probably difficult to be evaluated without real testing.

Finally, the measures of intention to use (BI) revealed that most of technicians intend to use MCAR. In fact, few respondents (20 and 25%, respectively, see Figure 4) stated that neither they would use MCAR in case they need support, nor they would like to have this device in their daily work. These results suggest that around 80% of

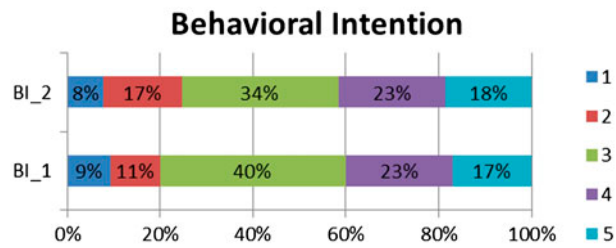

Figure 4. Results for behavioural intention (1 = strongly disagree to 5 = strongly agree).

technicians are willing to use MCAR; the resistances to face, in case this technology should be actually introduced, pertain to a small number of them.

4.2.3. Correlations and multiple regression analysis

Given that in the case of small samples, factor analysis often leads to unstable solution (Guadagnoli & Velicer, 1988), correlation and multiple regression analysis were used to investigate the relationships among constructs. To determine the correlation within PU, PEOU and Behaviour Intention, the Spearman's rank correlations coefficient was calculated. It is also used to describe the relationship of the independent variables and the outcome. For each construct, all the measurements resulted highly correlated with each other. Thus, the average score of the multi-items measures of each construct was computed, and this was consequently used in correlation analysis and regression analysis (Wang & Benbasat, 2007). As suggested by Wong and Hiew (2005), a correlation coefficient value (r) ranging from 0.10 to 0.29 should be considered weak, whilst in case it ranges from 0.30 to 0.49, it should be considered medium. Lastly, in case it ranges from 0.50 to 1.0, a strong correlation can be assumed. As shown in Table 4, all the constructs were positively correlated. In particular, we found a significant and strong relationship between PEOU and PU ($r = 0.680$, $p < 0.01$) as well as between PU and BI ($r = 0.520$, $p < 0.01$). Instead, a medium significant relationship between PEOU and BI ($r = 0.480$, $p < 0.01$) was identified.

In addition, a multiple regression analysis was performed to examine the effects of both PEOU and PU on BI. The results showed that PEOU did not significantly impact on BI ($p = 0.158$), whilst PU remains significant (see the results of the regression model of PU on BI in Table 5). In this latter case, the produced F-statistic was significant ($F = 26.459$; $p = 0.00$), thus confirming the fitness for the model. Moreover, the

Table 4. Correlations matrix and mean values.

Relationship	PU	PEOU	BI
Perceived usefulness (PU)	1		
Perceived ease of use (PEOU)	0.684**	1	
Behavioural intention (BI)	0.520**	0.492**	1
Mean	3.11	3.31	3.28
Std. deviation	0.98	0.99	1.13

$^{**}p < 0.01$.

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Table 5. Regression results BI = *f*(PU).

Model ($R^2 = 0.296$)	Unstandardized coefficients *B*	Unstandardized coefficients Std. Error	Standardized coefficients Beta	*t*	Sig.
(Constant)	1.322	0.398		3.321	0.001
PU	0.628	0.122	0.544	5.144	0.000

Dependent variable: BI

Table 6. Regression results PU = *f*(PEOU).

Model ($R^2 = 0.462$)	Unstandardized coefficients *B*	Unstandardized coefficients Std. error	Standardized coefficients Beta	*t*	Sig.
(Constant)	0.905	0.313		2.891	0.005
PEOU	0.667	0.091	0.680	7.359	0.000

Dependent variable: PU

coefficient of determination turned out to be equal to 0.296, thus around 30% of the variance of BI is explained by PU.

In order to understand if PEOU has a significant effect on PU, a second regression analysis was performed (see Table 6). In this case, even if PEOU appeared to not directly affect BI, PU turned out to mediate this relationship.

It is worth noticing that similar results were obtained by Shen and Eder (2009), Keil, Beranek, and Konsynski (1995), Rasimah et al. (2011) and Davis (1989). In particular, David Gefen and Straub (2000) claimed that a direct relation between PEOU and BI is significant, especially in case the core contents of the task are directly related to the intrinsic features of the technology, i.e. in case the task is an integral part of the technology itself. Conversely, in this study, the MCAR system is a tool, not a prosthesis (Hollnagel & Woods, 2005) of technicians, therefore it can enhance the user's ability, but its use is not necessarily mandatory.

Summing up, from this findings, it follows that the behavioural intentions to use MCAR in field services were mostly affected by the perception of usefulness, and only indirectly impacted by the PEOU.

5. Conclusions, limitations and future research

This study deals with the assessment of the perception of potential users of MCAR technology to support field service provision. In fact, as suggested by Nilsson (2008), the use experience can greatly affect the attitude of users towards a technology and, at the end, determines whether or not this technology will be used for a given purpose. Several aspects pertaining to different dimensions such as interface usability, user perceptions, fitting among contextual characteristics and technology features were observed and measured. Basically, through this holistic approach, it is possible to go beyond an impersonal evaluation of either the system's ergonomics or its functional performance. As confirmed by our study, even if some features of the MCAR system were pointed out as suggested improvements prior to introducing this technology as a working tool (e.g. the size and weight of the wearable equipment and the security of data transfer outside the customer's local network), the technicians involved in the demonstration as well as the 80% of respondents declared that they would be willing to use MCAR in their daily work. The intention to use MCAR, in fact, as confirmed by the multiple regression analysis, is mostly influenced by its PU, hence expected benefits rather than usability issues play the major role.

We believe that AR technologies will become, within a few years, a standard equipment of service network and maintenance departments. Therefore, managers should be aware of this, and be prepared to work for their adoption as soon as few technical restrictions will be overcome. To involve the different stakeholders (technicians, remote experts, R&D department, customers, etc.), it can be helpful resorting to demos, simulations, prototypes testing, etc. Besides assessing and controlling the resistances towards the wide-spread innovation of the service network, this could also be an occasion to rethink the ways field services are delivered. With respect to this latter possibility, we can draw out some considerations concerning the redesign of the service delivery system, as also suggested by several passages of the interview with *Informant A*. First of all, since MCAR allows a more efficient distribution of knowledge from R&D departments to the fields, its adoption will simplify maintenance tasks, will improve both efficiency and effectiveness of field interventions and, at the end, will contribute to lowering the cost related to the deployment of skilled technicians on large territories. As noted by *Informant A*, MCAR adoption will *change significantly when and how to train field force and so the kind of skills distributed on the field and in the back office*. Therefore, by means of MCAR, the delivery network could be redesigned through the introduction of a highly skilled central help desk to support field workers. Hence, field force could be mostly productive even with a simplified training programme. However, prior to deciding to reduce the efforts for training field technicians, labour unions relationships should be carefully managed, especially in large service networks.

Notwithstanding its relevance, this study has got some limitations as well, that leave room for future improvements. Firstly, since we used a single case study, the generalizability of our findings needs to be accurately addressed. With this respect, this research could be repeated in other contexts/companies, in order to extend the observation to other service networks as well as to increase the surveyed sample. A larger amount of respondents, in fact, would lead to more reliable analysis and, potentially, to the adoption of more sophisticated statistical methods such as SEM (Byrne, 2009). Finally, our investigation is based on TAM theory. However, as suggested by Goodhue and Thompson (1995), the use of conceptual models that consider also the extent of Task-Technology Fit could increase the predictive power of behavioural intentions. In fact, the fitting between technology features and work characteristics is also crucial to determine the success of a working tool in a business environment. Therefore, this latter is also recommended as an interesting avenue for future research.

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