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Influencing Factors for the Adoption of Speech Assistance in Manufacturing

Research Paper

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Abstract. In recent years, there has been a steady increase in the use of speech assistants in the private environment. Although such assistance systems would also be beneficial for manufacturing (for example, because workers have their hands free), speech assistants have not yet been widely used in the industrial environment. Against this background, we develop in this article a model with factors that influence the decision of industrial firms whether to adopt speech assistance for manufacturing. In order to do so, we rely on the Technology-Organization-Environment (TOE) framework and by interviewing 10 experts from firms that develop or use speech assistance solutions. Our model consists of 17 context factors that influence whether companies adopt speech assistance in manufacturing.

Keywords: Speech assistance, voice assistance, manufacturing, technology-organization-environment (TOE).

1 Introduction

Over the last years, there has been a rise in the usage of speech assistance in the fields of entertainment and smart home (Langen, 2022). Applications such as Siri, Google Assistant and Cortana can now be found on all mobile devices. So-called smart speakers are increasingly being used in private households. According to a recent study, 21 percent of Germans own at least one smart speaker and half of all Germans already use speech-based assistance in their everyday lives (Herz et al., 2022). This shows that speech assistance is already wide applied in the private sector. Due to their intuitive and simple operation, these systems are mainly used to retrieve information or to control smart devices in the household (Ammari et al., 2019; Maedche et al., 2019).

Despite this growing acceptance in the consumer sector, speech-based assistants are only applied to a limited extent in the manufacturing context. The only established industrial use case is pick-by-voice technology in logistics, in which an employee is guided to the corresponding goods via a headset and can call up speech-based information about them (Kalla & Seiter, 2021). However, speech assistance would offer

multiple advantages in the manufacturing domain. For example, speech as a form of interaction is more efficient than other forms because more information can be exchanged in less time. In addition, workers have their hands free and can move around freely, allowing parallel work to be carried out. This could lead to increased efficiency in maintenance processes or the control of technical equipment in production (Fischer et al., 2017; Langen, 2022; Udoka, 1991). Against this background, it is necessary to understand what factors lead to or hamper the decision of industrial firms to adopt speech assistance in their manufacturing processes.

Related literature already studied factors that influence the adoption of assistance systems (e.g., Meyer von Wolff et al., 2021; Rodriguez Cardona et al., 2019). However, these studies have a focus on digital workplaces or the insurance industry and it remains questionable if their findings can be generalized to assistance systems that primarily interact via speech and that operate in manufacturing processes with their particularities (e.g., loud background noises). Therefore, these studies only provide limited understanding regarding factors that influence the adoption of speech assistance in manufacturing environments. Reacting to that, we want to answer the following research question: *What factors influence firms' decision whether to adopt speech assistance in manufacturing processes?*

To answer this research question, we conducted 10 interviews with industrial experts that develop or use speech assistance systems and identified 17 factors that influence the adoption of such systems in manufacturing (Döring & Bortz, 2016). We structure these factors along the Technology-Organization-Environment (TOE) framework (Tornatzky & Fleischer, 1990). The remainder of this study is structured in the following way: First, we describe the research background regarding speech assistance in manufacturing and the TOE-framework. After a brief description of our methodology, we then present our results and the 17 factors. We conclude by discussing our results and limitations.

2 Research Background

2.1 Speech Assistance in Manufacturing

Speech assistance can be described as “a core technology for human-machine interaction [that] provide access to product offerings, information, and services via natural language” (Langen, 2022, S. 1). The interaction via natural language or speech has various advantages compared to the interaction via a Graphical User Interface (GUI). Since people talk faster than they type, speech interactions have a shorter conversation time. In addition, speech interaction avoids navigation through often complex graphical menus. Keyboards (e.g., on a screen) for typing are often small and therefore difficult to use. This is particularly a problem in manufacturing, where workers often wear gloves. Moreover, keyboards for typing need the use of hands and visual attention. This leads to distractions and work interruptions. A conversation via speech avoids these mentioned problems (Fischer et al., 2017; Langen, 2022; Udoka, 1991).

The architecture of a speech assistance system consists of five key elements, which are passed through in a process. First, the acoustic front end (AFE, such as a microphone) records the spoken words. These words are then transformed into machine readable text by using a machine-learning trained Natural Language Understanding unit (NLU). As third component, the dialog manager (DM) handles the conversation with the user and generates the response. As fourth and fifth components, the text-to-speech (TTS) and audio playback (AP) units transform this response into natural speech and play it back to the user (Langen, 2022).

Speech assistance can be applied in manufacturing for various scenarios. One scenario is the monitoring and control of industrial devices and machines (Langen, 2022). For example, Loch et al. (2018) describe the scenario where a machine for cleaning beverage bottles is controlled via a speech assistance system. Another application scenario is the maintenance of manufacturing equipment and machines. For example, such an assistance solution can guide service technicians interactively by providing instructions, checklists, and wiki pages. Moreover, such a speech-based assistance system can also be used as a training tool (Langen, 2022; Loch et al., 2018).

2.2 Technology-Organization-Environment (TOE) Framework

In literature few models have been proposed explaining the adoption of organizational technology on a firm level (Dwivedi et al., 2012). One of these models is the TOE framework, which describes that three groups of context factors (i.e., technological context, organizational context, and environmental context) explain the adoption of innovative technology (Dwivedi et al., 2012; Tornatzky & Fleischer, 1990).

First, the *technological context* includes all the technologies and their characteristics that are relevant to the firm (i.e., those ones that are already used by the organization and those ones that are offered on the market but not currently in use). Second, the *organizational context* describes resources and characteristics of the company (including linking structures, intra-firm communication processes, the amount of slack resources, and the firm size). Third, the *environmental context* describes “the arena in which a firm conducts its business – its industry, competitors, the macroeconomic context, and the regulatory environment” (Dwivedi et al., 2012, S. 235). Moreover, these three groups of context factors interact with each other and influence the decision of whether to adopt a new technology.

Since we seek to explain what factors influence industrial organizations whether to adopt speech assistance in manufacturing processes, we see the TOE framework as an appropriate underlying framework for this research. Moreover, the TOE framework has been widely applied for similar research (e.g., Demlehner & Laumer, 2020; Meyer von Wolff et al., 2021; Rodriguez Cardona et al., 2019).

3 Methodology

To identify the influencing factors on the adoption of speech assistance in manufacturing, we conducted interviews with industry experts following established methodological guidelines (Döring & Bortz, 2016; Schultze & Avital, 2011). In general, we applied a three-step approach.

First, we selected our interview partners. For this purpose, it is first necessary to define who can be considered as an expert for our interviews. We identified two groups of possible interview partners. One group includes employees of companies from the manufacturing sector that currently implement or already use speech assistance. The second group consists of the software developers who offer speech assistance solutions for the manufacturing environment. Moreover, another requirement was that our interview partners have multiple years of experience in the field of industrial speech assistance. In the first group (the users of speech assistance), we distinguished on the basis of roles between managers and shop floor workers. For the second group (the providers of speech assistance), we distinguished between the roles of sales representatives and software engineers. We tried to conduct interviews with both groups and each both roles in order to get a comprehensive overview of the relevant factors. In total, we conducted 10 interviews. Table 1 provides an overview of our interviewed companies, the interviewed employees and their roles.

Table 1. Overview of our interview partners

No.	Function	Sector	Size	U/ MA	U/ SF	P/ SA	P/ SE
1	Engineer	Cert	SME		X		
2	CEO	Auto	SME	X			
3	Engineer	Aero	LE		X		
4	Senior AI Develop.	ICT	LE				X
5	Project Manager	ICT	LE				X
6	Head of Sales	ICT	SME			X	
7	Sales Manager	ICT	SME			X	
8	Energy Manager	Auto	LE		X		
9	CEO	Auto	SME			X	
10	Project Manager	Auto	LE			X	

Abbreviations: (1) Groups and roles: U/ MA: User/ Manager; U/ SF: User/ Shop floor worker; P/ SA: Provider/ Sales representative; P/ SE: Provider/ Software engineer (2) (Firm) size: SME: Small and medium-sized enterprise; LE: large enterprise (3) Sector: Aero: Aerospace; Auto: Automotive; Cert: Industrial certification; ICT: Information and communication technology;

Second, we conducted 10 semi-structured interviews remotely via a conference system between January and May 2022. The interviews lasted in average between 30 and 60 minutes. One longer interview took two hours. The structure of the interview questions followed the TOE framework. First, we asked for the factors included in the TOE framework (e.g., about the regulatory environment for the environmental context). Then, we continued with open question to identify more factors. We recorded the interviews and transcribed them.

Third, we relied on a structured approach to analyze the content of the interview transcripts. In particular, the first author developed codes (open coding) and assigned them to the three contexts described in the TOE framework. These codes were then the basis for the formulation and structuring of the identified factors (axial coding). Since we conducted our interviews in German, we translated the final coding and the factors into English. To improve the reliability of the coding, the second author checked the coding results.

4 Results

Our study identified 17 factors explaining whether firms adopt speech assistance for manufacturing. We structure these factors along the three dimensions of the TOE framework (see Figure 1).

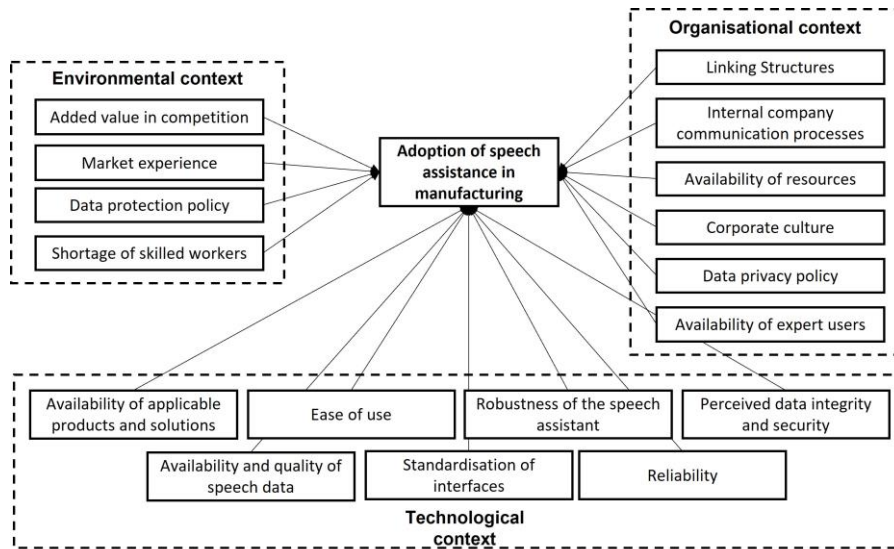


Figure 1. Adoption of speech assistance in manufacturing processes

4.1 Environmental Context

A central reason for introducing new technologies is to generate added value in order to prevail in an intensely competitive environment (Phillips & Schirmer, 2008). However, according to the interviewees, speech-based projects have a high initial expense and the benefit varies depending on the use case or is sometimes difficult to express in monetary profit before introducing the system. Overall, the interviewees expect a gain in efficiency, which is expressed, for example, through shorter throughput times or less downtime. In some use cases, even personnel can be saved or employees can be deployed in a more targeted manner. This is mainly due to the possibility of parallel work with the free hands and the increased mobility or independence of location. Overall, the

expected added value in a competitive environment has a positive influence on the introduction of speech assistance, which is why the following assumption was made: *A1: The higher (lower) the expected added value in a competitive environment, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

According to the interviewed experts has the availability of market experience an influence on the adoption of speech assistance. If there are more firms that already adopted speech assistance and/ or developed and implemented such solutions (e.g., consultants), the more firms can share their experience (Langen, 2022; L. Wang, 2022; Xu et al., 2021). This would lead to a better dissemination of this technology, as the following statement exemplifies: *"You already break down the barriers for each other with the customers if the introduction of speech assistance has already been considered [by others]"* (Expert 6). However, according to the respondents' assessment, there is currently limited experience on the market. Once this hurdle is overcome, most respondents expect that speech assistance-based solutions will become more widespread in the future. Based on this assessment, the following assumption could be derived: *A2: The more (less) experience in the market, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

One regulatory topic that was particularly mentioned in connection with speech assistance systems are data protection guidelines (e.g., General Data Protection Regulation by the EU). The main objective of this regulation is protecting personal data (De Lacerda & Aguiar, 2019). According to the interviewees, this leads to considerable restrictions in the design, selection, and usage of speech assistance systems. For example, it has an impact on where the data may be stored or where the speech model is trained. According to the impressions described in the interviews, the following assumption can be formulated: *A3: The stricter (looser) the legal data protection guidelines are, the lower (higher) the probability that companies will adopt speech assistance for manufacturing.*

The last identified external influencing factor refers to the lack of skilled workers in the manufacturing domain (Klapper et al., 2019). According to the interviewees, by using speech as an intuitive and suitable way for interaction, such assistance systems offer the possibility to collect domain-specific process knowledge and to use it for the training and instruction of new employees. If the system is intelligent enough, it can also be adapted to the employee's qualifications and experience. Accordingly, the following assumption can be made: *A3: The higher (lower) the shortage of skilled workers, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

4.2 Technological Context

Another factor is the availability of necessary products and solutions (Dwivedi et al., 2012). This factor was considered important by almost all interviewees. They referred to multiple hardware and software solutions that are crucial for developing, implementing, and using speech assistance in manufacturing. These products and solutions can be single components (e.g., a microphone/ a speech-to-text software) or the whole system consisting of multiple components (e.g., the final software system that talks via speech

with the user). Moreover, the interviewees mentioned that the performance of these relevant products and solutions increased within the last years, which has a positive effect on adopting speech assistance. Correspondingly, we formulated the following assumption: *A4: The higher (lower) the availability of applicable speech assistance products and solutions on the market, the higher (lower) the likelihood that companies will adopt such solutions for manufacturing.*

Speech data is the basis for training a language model that transforms spoken words into machine-readable text (Langen, 2022). Accordingly, the availability and quality of speech data could be identified as a general influencing factors for the adoption of speech assistance. There are pre-trained language models (e.g., provided by Google) for the speech-to-text conversation. However, the interview partners highlighted that the language model must be adapted to the specific technical vocabulary in the desired manufacturing domain. Some data, such as end-user formulations, are not available in the pre-trained language model, but have to be worked out during the speech assistance development/ set-up (Runkler, 2010; Wang et al., 2021). Overall, the following general assumption can be made: *A5: The higher (lower) the availability and quality of speech data, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

Another influencing factor identified was the ease of use or user-friendliness of the speech assistance (Davis, 1989). The core idea of all interviewees was that the use of speech assistance solution must be as simple as possible as the following statement shows “*ideally the speech assistant is so intuitive that [the manufacturing worker] does not have to learn much new*” (Expert 4). To reach this ease of use, the interviewees emphasized some design characteristics of the speech assistance solution. First, the speech assistance system should minimize waiting times. This means that the user does not want to wait long on the systems response to a speech input. Second, the correct structuring of the dialogues also leads to easier operation. Overall, suppose the processes and timings of the dialogue match the employee's working methods and the employee can enter the queries intuitively with the application-specific vocabulary. In that case, this ensures that the system integrates seamlessly and the employee hardly has to learn anything new. According to the respondents, this positively influences the acceptance of the systems, which leads to the following assumption: *A6: The easier (harder) it is to use speech assistants, the higher (lower) the probability that companies will adopt such solutions in manufacturing.*

On-site conditions pose a particular challenge in the industrial sector. In addition to the loud noise caused by technical equipment, the speech assistant system must also be able to deal with harsh physical conditions (e.g., wetness and dirt) (Fischer et al., 2017; Loch et al., 2018; Mayer & Pantförder, 2014; Scharfe et al., 2022). Accordingly, not only the algorithms of the speech recognizer are in demand here, but also the selected hardware must be correspondingly robust. According to the interviewees, very specific headsets are used to deal with the mentioned environmental conditions. Modern microphone technology also supports the filtering of background noise and facilitates further processing by the software. In some cases, several microphones are used to better separate the interfering signal from the useful signal. Based on interviewees' statements,

the following assumption can be derived: *A8: The more robust (vulnerable) the solutions are against harsh settings, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

Another influencing factor is the standardization of interfaces (Stich et al., 2015). The interview partners highlighted that speech assistance systems are often connected via interfaces with other software systems in the manufacturing environment (e.g., machine control systems or manufacturing management systems). To enable limited efforts to connect the speech assistance system with these other systems the speech assistance one should have standardized interfaces. This leads us to the following assumption: *A9: The higher (lower) the degree of standardization of the interfaces of the systems to be connected, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

According to the interviewees, a particular problem with speech-based data interaction solutions is the perceived integrity of the data. The following statement by Expert 4 sums up this observation well: *"The general fear of employees with speech assistants is that they will be bugged and that bosses will be able to track what they have done and when. This fear is actually unjustified due to data protection laws"*. End users are therefore afraid of data misuse. From the point of view of the providers of such solutions, however, this is unjustified because the software prevents such use of the data due to legal regulations. According to the interviewees, appropriate transparency must be created to allay users' concerns. For this, employees using speech assistance must be informed about data storage and processing. Against the background of these observations, the following assumption was made: *A10: The better (worse) the perceived data integrity, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

Another key factor from a technological perspective is the reliability of the speech assistance system (Loch et al., 2018). Our interview partners also confirmed this. The following statement of a speech assistance provider illustrates the importance: *"if I were to present [the product] and three values did not work [...] then it would be rejected immediately [by the customer], no matter what was good before [...] we must not have an error rate that is greater than 1.5 to 2 %"* (Expert 6). Accordingly, not understanding or misunderstanding the speech input or a not understandable speech output can have fatal consequences, especially in industrial environments with high efficiency and safety demands (Loch et al., 2018). This leads to the following assumption: *A11: The higher (lower) the reliability, the higher (lower) the probability that companies will adopt speech assistance for manufacturing.*

4.3 Organizational Context

So-called 'linking structures' refer to interdepartmental structures (e.g., enabled by IT systems) within an organization and the information exchange they provide (Dwivedi et al., 2012). According to the interviewees, these structures make it possible for a (speech-based) assistant system to connect different departments. For example, by linking information from the production department with that from the warehouse depart-

ment, employees can call up the availability of materials directly in the production process. Therefore, such linking structures lead to increased efficiency. Against this background, the following assumption was made: *A12: The better (worse) the linking structures in a company are, the higher (lower) the probability that this company will adopt speech assistance for manufacturing.*

Another influencing factor are the company's internal communication processes. It was pointed out that any new technology must be communicated well to the manufacturing employees. Therefore, the interviewees argued that a good communication strategy is necessary to reduce the obstacles and reservations towards speech-based solutions as a new technology. Overall, the following assumption can be made: *A13: The better the company's internal communication processes are, the higher (lower) the probability that this company will adopt speech assistance for manufacturing.*

The interview partners referred to various resources that are necessary for the adoption of speech assistance. In addition to the necessary capital, the availability of staff and time play an important role. Moreover, two respondents pointed to the necessary (IT) infrastructure as another resource (Langen, 2022). Based on these findings, the following assumption can be made: *A14: The greater (smaller) the availability of an organization's resources, the higher (lower) the probability that this company will adopt speech assistance for manufacturing.*

Based on the interviews, corporate culture was also identified as another influencing factor. The interviewees pointed out that employees, especially management, must be open to innovative technologies (such as speech assistance). Overall, this leads to the following assumption: *A15: The more innovative (conservative) the corporate culture, the higher (lower) the probability that this company will adopt speech assistance in manufacturing.*

Another topic described in detail by our interview partners are company guideline restrictions through internal company regulations on data storage and transfer (Langen 2022). These guidelines either originate from the company management or are set by the works council. A frequently discussed point is the preference for on-premise solutions over cloud-based approaches. This makes implementation more expensive, as companies have to provide the necessary infrastructure themselves and update it regularly. Overall, these restrictions have a strong inhibiting effect and, in many cases, ensure that the adoption process stalls and existing solutions cannot be used. For this reason, the following assumption can be made: *A16: The stricter (looser) the companies data privacy policies are, the lower (higher) the probability that this company will introduce speech assistance in manufacturing.*

The last organisational influencing factor identified was the availability of expert users. According to the statements of our interview partners, an early involvement of expert users from manufacturing (e.g., those who know production processes and the used designations) is indispensable for a successful development and adaptation of the speech assistance solution to the needs of the user company. Special process knowledge is needed to create the dialogues. Through early feedback, special user needs and ways of working can be recognised and taken into account in the speech assistance system. As these expert users are involved in the company's daily business, it is often a challenge to involve them. However, their involvement increases the user-friendliness of

the speech assistance system and the associated acceptance. Based on these findings, the following assumption can be made: *A17: The higher (lower) the availability of expert users, the higher (lower) the probability that this company will adopt speech assistance in manufacturing.*

5 Discussion

In our study, we identified 17 factors explaining whether firms adopt speech assistance in manufacturing processes and structure them along the three dimensions of the TOE framework. Our study contributes to practice and research.

For the field of research, we contribute to the literature that focuses on factors whether firms adopt (speech-based) assistance systems (e.g., Meyer von Wolff et al., 2021; Rodriguez Cardona et al., 2019). While some of the identified factors (e.g., added value in competition) were also identified in a similar way by these other studies, some factors (e.g., robustness) are rather unique for the specific application scenario of manufacturing. Moreover, we point to some general factors that are not manufacturing specific and have been highlighted only to a limited extent in the existing literature (e.g., perceived data integrity and security). This allows to develop general factors that are necessary for the adoption of (speech-based) assistance systems. Moreover, our 17 factors could be the focus of future research. For example, scholar could investigate how these factors (e.g., a corporate culture that supports the adoption of innovative technologies) can be implemented in companies. This would support the adoption of speech-based assistance systems. Generally, our interview partners rated the potential and possible added value of such assistance systems as high. Moreover, our study is also beneficial for practitioners. (Potential) users of speech assistance or their consultants could use our factors as assessment tool to decide whether speech assistance is a suitable solution for their manufacturing processes.

As any study, our research also has some limitations. First, we only rely on a limited number of interviews. We tried to minimize that limitation by interviewing partners who provide different perspectives (e.g., users and developers of such solutions). However, in the future our results could be verified at a larger scale (e.g., by conducting a survey in the manufacturing field). Second, we did not evaluate the strength of the different factors. Maybe some factors have a higher influence on the decision whether to adopt speech assistance. This could be another starting point of future research.

In conclusion, we hope that our study provides more insights to research and practice on whether to adopt speech assistance as an innovative technology in manufacturing processes.

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