The Adoption Of Artificial Intelligence In SMEs - A Cross-National Comparison In German And Chinese Healthcare

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Abstract. Artificial Intelligence (AI) as an emerging technology is increasingly applied in the healthcare sector. Moreover, the AI-related progress and technology application is not only driven by traditional companies but even more by the establishment of small and medium-sized enterprises (SME) in healthcare, the innovation process as well as dynamic product development in the very same organizations. We chose a multiple-case study design using expert interviews with 14 SMEs, equally distributed from China and Germany to analyze the adoption of AI in healthcare SMEs. Our results contribute to current empirical research with a cross-national comparison in Germany and China on the status of AI development and adoption, the perceived advantages and challenges of AI, as well as the expected future development and implementation of AI in healthcare in the upcoming five years.

Keywords: Artificial Intelligence · Adoption · Healthcare · SME · Digital Transformation · Germany · China · Benefits · Challenges · Qualitative-Empirical Study · Interview Study.

1 Introduction

Artificial Intelligence (AI) is rapidly being applied to a wide range of fields, including healthcare. It has been considered as a technological approach that may augment or substitute human professionals in healthcare [1]. With recent progress in digitized data acquisition, machine learning, and computing infrastructure, AI applications are expanding into areas that were thought to be reserved for human experts [2]. A significant application in healthcare is collecting, storing, normalizing, and tracing data [3], where AI has the potential for doing transformative work, such as mining medical records, assisting repetitive jobs [4], intelligent decision support in diagnosis or to correct medical decisions [5, 6]. In the future, AI could further support digital transformation and revolutionize the

information supply of healthcare practitioners and executives as well as their interaction with patients, clinical and operational staff [6, 7].

China is a leading global AI development hub with a vast population and industry mix that can generate a great data volume and provide an enormous market [8]. McKinsey Global Institute published a study in 2017, that estimated, half of all work activities in China could be automated, illustrating the nation's automation potential [8]. The Chinese State Council issued a guideline in 2018 to improve healthcare service efficiency [9]. According to the 'Made in China 2025' (MIC25) plan, the healthcare sector is prioritized in many ways. AI, one of the industry-spanning core elements covered by MIC25, is expected to have a significant impact on the transformation of healthcare [10]. In 2019 China was Germany's most important trading partner for the fourth year in a row and both started the deployment in digital technology to create new industrial environments, produce new products, and improve established brands [11, 12].

In contrast to various studies on AI applications, e.g. in form of wearable devices [13] or autonomous robotics [14], few studies have spotlighted the current status of AI development and the prospects of AI technologies from the company perspective. To fill this research gap, a qualitative-empirical study using semi-structured interviews was conducted with Chinese and German small and medium-sized enterprises (SME) in healthcare, especially in micro and small companies. Compared to global players, startups show significant differences in acquiring and processing data as well as a differing philosophy and unique dynamism [15]. In total, managers of 14 healthcare SMEs (equally from Germany and China) were interviewed to investigate the benefits and challenges regarding the adoption of AI as well as the future technological development in 5 years' time, including organizational requirements to adapt for a future with AI.

2 Related Work

The literature review consists of two parts: first, we review research on AI in healthcare in terms of AI-driven applications, challenges in AI development, and healthcare SMEs. Second, we present an overview of several representative empirical studies on AI and digitization.

2.1 Artificial Intelligence in Healthcare

As AI in healthcare becomes more widespread, a wealth of theoretical research on AI applications is emerging. One of the most prosperous areas to use AI is automated medical image diagnosis, where AI-powered algorithms have made inroads in medical specialties including radiology, ophthalmology, pathology, and dermatology [2, 16, 17]. In addition, wearable devices [2, 18], autonomous robotic surgery, [14, 19] and patient care [20–22] are relevant scenarios for AI applications. Although AI promises to revolutionize medical practice, many challenges lie ahead. Obermeyer et al. have noted that AI algorithms might 'overfit' predictions to spurious correlations in the data, leading to exaggerated claims about

real-world performance. Data from different healthcare environments can contain various types of bias and noise, which may cause a model, trained on one hospital's data, to fail to generalize to another. They pointed out that the quantity and quality requirements for input data in AI applications may need an upgrade of the current databases [23]. Bartoletti highlighted that AI in healthcare will also challenge the boundaries of current regulatory systems and privacy principles. For him, it is essential to adopt a cautious approach in order to maximize the positive whilst reducing the risks of privacy, bias, and ethics harms [24].

2.2 Empirical Studies

Compared to the extensive theoretical studies on AI applications, there are relatively few studies that explore the current status and prospects of applying new technologies like AI in the form of empirical studies, especially those employing interviews or questionnaires to collect data. Table 1 shows a brief review.

Table 1: Literature Review - Adoption of emerging technologies including AI

Paper	**Objective**	**Method**	**Sample**	**Findings**
Leung (2019), [25]	Views of hotel stakeholders in Taiwan on smart technology	Interview	9 (Taiwanese)	No clear definition of smart hotel; several barriers that prohibit hotel owners in implementing smart systems
Sun and Medaglia (2018), [26]	Challenges of AI in the public sector	Interview	18 (Chinese)	Stakeholders have diverse, and sometimes contradictory, opinions of the challenges
Brooks et al. (2020), [27]	Pressures and challenges of AI in legal	Interview	18 (British)	Professional norms, tradition, and culture maintain existing structures and business models facing a technological change
Laï et al. (2020), [28]	Perceptions of French stakeholders on AI in healthcare	Interview	40 (French)	The development of AI tools in healthcare would be satisfactory for everyone only by initiating a collaborative effort between all those involve
Wangmo et al. (2019), [29]	Ethical issues of intelligent assisting technology (IAT) in elderly and dementia care	Interview	20 (European)	Clear disagreements among professional stakeholders regarding solutions for ethical challenges and the adoption of strategies to implement IAT safely and effectively
Nelson et al. (2020), [30]	Patients' opinions of the use of AI for skin cancer screening	Interview	48 (US)	Patients are receptive to AI for skin cancer screening if applied in a manner that preserves integrity of human physician-patient relationship

Table 1: (continued)

Blease et al. (2019), [31]	View of general practitioner (GP) on impact of future technology in primary care	Questionnaire	720 (British)	Most GPs considered the potential of AI to be limited because of the lack of communication and empathy of this future technology
Ye et al. (2019), [32]	Public acceptance of ophthalmic AI devices	Questionnaire	474 (Chinese)	Underdeveloped AI use in clinical laboratory analysis & diagnostics; mistrust of medical AI systems in Chinese public
Lackes et al. (2020), [33]	Affects on acceptance of intelligent personal assistants (IPA)	Questionnaire	129 (mainly German)	Trust in the manufacturer affects trust in IPA and perceived advantages; trust in IPA influences the perceived advantages & disadvantages as well as the acceptance
Bérubé et al. (2021), [34]	Barriers regarding AI implementation in organizations	Interview	18 (French, Canadian)	Lack of data-related organizational capabilities and of AI experts; generic implementation barriers

Multiple studies focused on the healthcare industry [28–32], while others investigated areas like the public sector [25] or legal [27]. Various studies used interviews [25–30, 34], and questionnaires [31–33, 35] to collect data. Regarding the choice of interviewees or respondents, most researchers looked at stakeholders of AI technology and products [25–29, 31, 34], or targeted the potential purchasers of AI products and services [33, 35] as well as patients [30, 32]. There are few empirical studies on AI application in healthcare, and to the knowledge of the authors no studies that considered healthcare SMEs as research subjects. Furthermore, most studies have sampled from one country rather than making a cross-national comparison. To fill this research gap, this paper aims for an alternative perspective by interviewing German and Chinese healthcare SMEs. The analysis and comparison of the interview results support the further exploration of AI's development status and adoption in healthcare SMEs in both countries.

3 Research Design

This section describes the research design and the research method, including data collection and analysis. We apply a case study research approach to answer: how is the adoption of AI among German and Chinese healthcare SMEs and what are the differences between the results of both countries?

3.1 Method

Case studies are a design of inquiry found in many fields. The researcher conducts an in-depth analysis of a case, often a program, event, activity, process, or one

or more individuals. Cases are bounded by time and activity, and the researcher uses a variety of data collection procedures to collect detailed information over a sustained period of time [36,37]. According to Yin [37], a general definition of a case study has two main parts: (a) The scope of a case study: Investigating a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident; and (b) a case study's features: The situation where there will be many more variables of interest than data points, thereby relying on multiple sources of evidence and benefiting from the development of theoretical propositions to guide data collection and analysis [37]. Case studies are especially suitable when it comes to *how* and *why* questions are being asked about a contemporary set of events over which a researcher has little or no control [37].

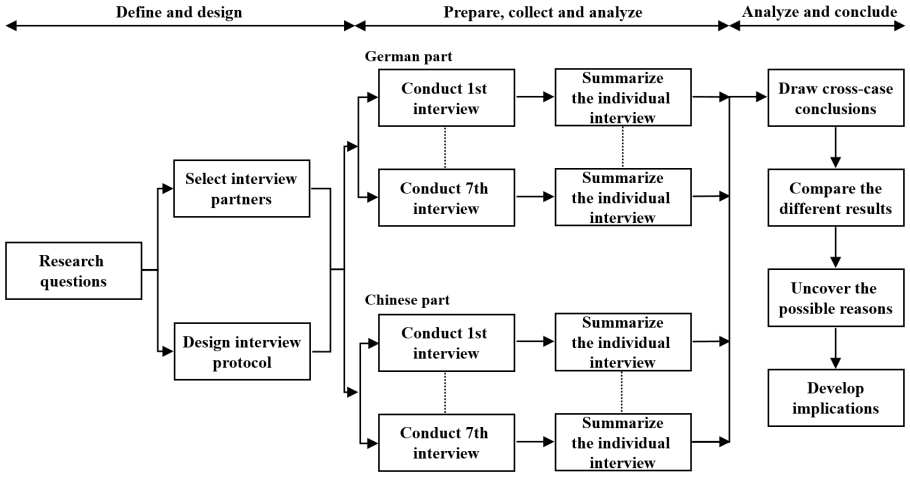

Fig. 1: Research Procedure following Yin [37]

We chose a multiple-case study design with expert interviews to collect primary data. Each case can be represented by an interview that reflects the company's AI use. The general research procedure is shown in Fig. 1. This flowchart, as described by Yin [37], illustrates the primary steps of the empirical part.

3.2 Setting

The setting consists of a German and a Chinese perspective (see Fig. 1), which consist of interviewing suitable experts found in the preparation phase. In total seven healthcare SMEs from each country were interviewed. Table 2 summarizes the 14 interviews.

The selection of German interviewees is mainly centered on the members of the *Medical Valley Europäische Metropolregion Nürnberg*. It is a leading international cluster in the field of medical technology, medicine, and health [41]. After

Table 2: Demographic characteristics of participants and related SMEs

Firm	Est.	Employees	Job Description	Location	Primary Business
G1	2014	70-80	Product Manager	Munich	Medical Imaging
G2	2019	15	Co-Founder/CEO	Munich	Structured Data Platform
G3	2016	6	Co-Founder/CEO	Erlangen	Medical Sensor Systems
G4	2018	<10	Managing Director	Erlangen	Medical Imaging
G5	2019	15	Co-Founder/CEO	Würzburg	Surgical Robots
G6	2016	53	CEO	Erlangen	Medical Imaging
G7	2014	∼50	Senior Consultant	Fürth	Medical Database
C1	2017	10	CEO	Shenyang	Medical Imaging
C2	2015	180	CEO Assistant	Shanghai	Medical Service Robots
C3	2015	12	CEO	Shenyang	Medical Information Management
C4	2010	16	Deputy CEO	Shanghai	Medical Equipment Asset Management
C5	2014	20	Founder/CEO	Shanghai	Medical Imaging
C6	2012	40	CEO	Shanghai	Medical Imaging
C7	2012	41	CEO	Beijing	Medical Imaging

passing the initial screening the companies were selected as potential interviewees, and interview invitations were sent to the founders, CEOs, or qualified technical staff. For the selection of the Chinese SMEs, an expert recommendation approach was adopted for optimizing the selection of interviewees. Several industry experts with in-depth knowledge of and contact with Chinese healthcare SMEs were chosen as direct contacts who make company recommendations. The selected potential interviewees were contacted respectively and invited for the interviews. For Chinese interviewees, WeChat was chosen as the primary communication tool. Companies were filtered by business type: they had to be involved in the healthcare industry, and by company size: they had to fulfill the European Commission's definition of SME [42].

3.3 Data Collection and Analysis

Case study data collection is crucial and involves a wide range of procedures as the researcher builds an in-depth picture of the case [39].

Interviews are commonly used in case studies as a form of data collection to obtain primary data, consisting of asking open-ended questions to participants [40]. The interview protocol design follows the procedures from Yin [37] and Creswell [40]. It starts with questions on the AI background and if the company already applies AI. If they do so, questions are asked about AI implementation, AI benefits and challenges, and future possibilities. If they do not use AI, questions are asked about reasons for not using AI, the general prospect of AI, and further plans about AI.

All interviews were conducted online and recorded with the interviewees' consent in order to preserve the data for subsequent analysis. A combination of automatic machine transcription and follow-up manual correction is used in the transcribing process. The interview languages are English and Chinese. For the English audio, the transcription is carried out using the automatic speech recognition function provided by YouTube [43], whose transcription function has a lower word error rate and therefore better performance [44]. For the Chinese audio processing, a transcription software called iFlytek Hears is chosen [45]. The interview data is first transcribed into Chinese text form, and then further translated into English using the translation software DeepL and manual corrections. Finally, the English translations are combined with the English interview transcripts to form the primary data set of this study.

Following Yin [37], the collected data was imported, organized, and analyzed systematically. After collecting all interview information, the demographic characteristics of interviewees are summarized to gain an overview of the interviewed companies. Secondly, each question's results are analyzed as a whole, then separately within and between countries, to inquire the similarities and differences. Specifically, in the analysis of questions on the benefits and challenges of AI use, descriptive analysis is used to count the frequency of the occurrence of each response among the interviewees, as the responses are relatively homogeneous.

With the results of all interview questions collated and aggregated separately, the interview questions are then grouped according to the sub-questions they describe. Among the interview questions, the ones regarding AI background and AI implementation do not cover specific research questions. Therefore, the responses from the two sections are used to measure an overall attitude towards AI among SMEs. The results are represented in the form of a matrix for a more visualized exploration in terms of cross-national comparison. For each sub-question, the corresponding interview questions are summarised and compared to investigate the differences in answers between both countries.

4 Results

After presenting the research design and the interviewees, this section will have a stronger focus on the twelve SMEs (5 German, 7 Chinese) who were declared as AI adopters. The taxonomy of AI adopters and non-adopters followed out of the interviewee's answers regarding the AI importance for the companies' business as well as the organizational capabilities to apply AI.

4.1 Implementation Fields of AI

Two German (G3, G4) and five Chinese (C1-4, C6) SMEs considered AI as a core element and central for their business. Another four firms, two from each country (G1-2, C5, C7), confirmed the importance of AI but estimated the AI influence is still limited. Therefore, AI plays a supporting role in products and services or is seen in the research and development phase. Three German SMEs (G5-7) perceived AI as relatively unimportant to their business. Two of those had no plans to develop AI and according to their lack of capabilities did not apply AI so far. This study investigated different application scenarios in healthcare SMEs and looked at the AI adoption by the following two dimensions (see Table 3).

Table 3: Application Scenarios of Artificial Intelligence

	Product Component	**Product Core**
AI in Research	G1	G3, G4, C5, C6
AI in Use	G2, G5, C7	C1, C2, C3, C4

On one hand, the AI usage is classified as product component (integration in products for the optimization of functionalities), or product core which implies AI as absolutely relevant for the product and its functionality. On the other hand, two categories of the current stage of AI development are distinguished: AI in the research stage or AI already applied to products or services.

4.2 Benefits and Challenges of AI

Depending on the company background and the current AI development stage, the German and Chinese experts named multiple benefits (see Fig. 2) as well as challenges (see Fig. 3) that accompany the AI implementation within their organizations. The percentages are calculated separately for the two countries to eliminate the differences in the number of interviewees.

All twelve AI adopters highlighted 'efficiency improvement' as a benefit, that manifests in e.g. speeding up data and image processing (G1-5, C1, C5-7) or improving management efficiency (C2-4). 'Selling point' was mentioned by eight companies as an advantage to convince investors and to highlight the innovativeness of AI-driven specifications. Furthermore, AI is seen as a technology that leads to better performance compared to humans or traditional algorithms. Higher accuracy (C4-5, C7), better data processing (G3-4), path planning for medical robots (C2), or the ability to find solutions for existing problems (G1) are linked to this benefit category. Additionally, 'talent attraction', 'avoidance of human error' e.g. due to fatigue, 'cost reduction' because of fast and accurate data processing or labour cost savings, and 'workload reduction for physicians' to enable more patient quality time were discussed. Especially regarding the last four benefits, a differentiated view of Chinese and German experts is observed.

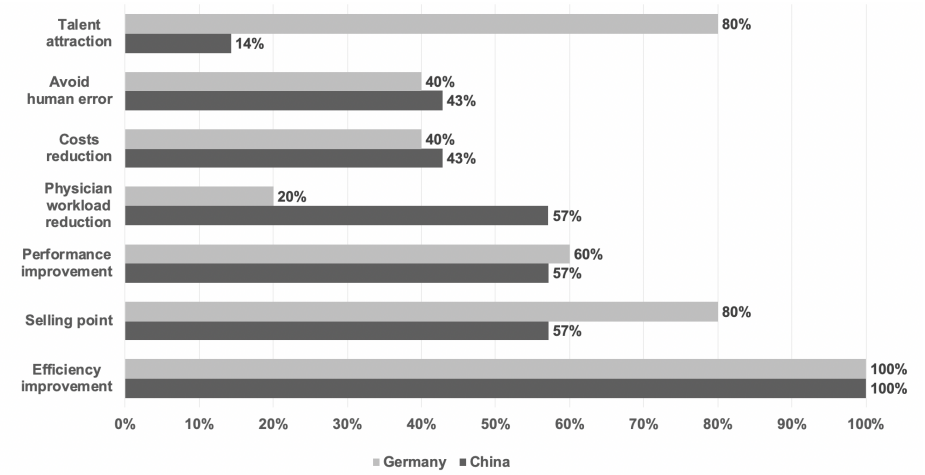

Fig. 2: Benefits of AI in German and Chinese healthcare SMEs

Similarly, Fig. 3 summarizes the main challenges named by healthcare experts according to the adoption of AI in their organizations.

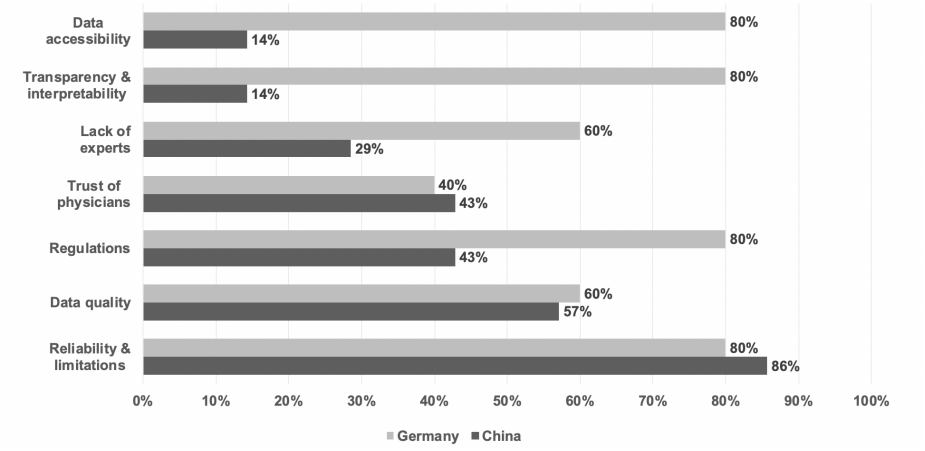

Fig. 3: Challenges linked to AI in German and Chinese healthcare SMEs

Ten interviewees showed a consistent opinion regarding 'reliability and technological limitations', concerning the current AI accuracy and needed supervision (G3, C1, C5-7) or existing issues of non-reproducibility and robustness in heterogeneous environments (G2-3). In terms of 'data quality', as a result of non-standardized and unstructured data (G1, G4-5, C1, C5-7), and the lacking 'trust of physicians' in AI products and services (G3-4, C3, C5, C7) experts from

both countries had a mutual understanding. Nevertheless, when looking at 'data accessibility', 'transparency & interpretability', e.g. insufficient traceability and causality of AI decision-making processes, as well as 'regulations' and 'lack of experts' the majority of German representatives underlined stronger concerns compared to Chinese counterparts.

4.3 Prospective AI Development and Non-adopters of AI

A positive view on the future development of AI in the upcoming five years was observed more from Chinese (C2-4, C6) than from German experts (G2, G4). Chinese representatives expect an increasing trend of AI in the healthcare sector and a further boost to their business. Activities in Chinese politics to promote digital transformation and intelligent management in hospitals are seen as contributions to AI development. From a technical perspective, they still expressed concerns regarding the maturity of AI applications, e.g. to make autonomous decisions in the early future. Moreover, German SMEs underlined a prospective AI development in personalized medicine and within applications to support diagnostic and therapeutic solutions for individual patients. Healthcare SMEs from both countries expressed a mixed (G1, C5) or negative view (G3, G5, C1, C7) when explaining their expectations in the next five years. Optimism regarding an increase of AI-related healthcare companies goes along with skepticism when looking at the cooperation with physicians and the 'unlikable replacement' of physicians in the future. The negative concerns have their origin in the lack of AI experts and strict regulations, named mainly by German managers.

As mentioned at the beginning of the results section, there were two companies (G6-7) that have not adopted AI so far. Both interviewees were neutral regarding the outlook of AI. On one hand, they could imagine the benefit of AI in supporting customers to reduce their workload and its ability to potentially make its own decision. On the other hand, they were pessimistic according to regulations and their dependence on further research and development in the field of AI. Both non-adopters prefer cooperation with external AI-skilled companies instead of independently deploy AI within their organizations in the future.

5 Discussion

This study investigated the AI implementation in four areas based on the dimensions of AI importance and current stage to fill the research gap in empirical research addressing the AI application in SMEs. After the analysis, no Chinese and only one German company is located in the area 'AI in Research x Product Component'. The stronger focus especially of Chinese SMEs on AI adoption as product core and their status being in the AI in use than in the research phase can be named as reasons. This outcome might be explained by the Chinese policy to encourage the opening of healthcare data, the digitization of hospitals and AI in healthcare [9]. Beyond, no German company is located in the area 'AI in use x Product Core'. This absence is justified by the maturity of AI applications

and declared as in research phase or as product component. The situation reflects the stricter regulations in German healthcare industry [46] and 3-4 years to conduct a clinical validation and get the medical device certification (G3).

Experts from both countries had a consistent understanding of three main AI benefits when looking at performance and efficiency improvement as well as AI as a selling point. Nevertheless, German interviewees valued AI more with 80% for its effect in terms of talent attraction and easier recruitment compared to only 14% in China. This significant difference could reflect the higher demand for AI talents in Germany and is evident in the identified challenge and lack of AI experts. These findings approve previous exploratory studies, which concentrated on French and Canadian experts and allow a deeper comparison of the national circumstances [34]. When looking at AI application fields, a distinct opinion can be observed. A 57% ratio in China versus 20% in Germany sees the workload reduction as the main AI benefit. The higher product amount with AI in use in Chinese companies as well as the stronger focus on physician- than on patient-oriented products and services may explain this outcome.

In the perceptions of AI challenges, there are significant disparities between Germany and China. German interviewees not only named more challenges but also the corresponding percentages when looking at data accessibility as well as at transparency and interpretability are noticeably higher (80% versus 14% each). The perception of more barriers to AI use in German healthcare SMEs may objectively be explained by more difficulties in implementing AI (e.g. caused by stricter data protection laws or healthcare approvals) but also by the increased desire for a better understanding and explainability of AI. These findings go along with the barriers to AI implementation, presented by Berubé et al. [34], who identified the lack of high-quality data and data governance issues as crucial. They focused on the adoption in all types of organizations. Our study contributed to close the gap in investigating one particular type and focused on healthcare SMEs. Meanwhile, it is worth noting that Chinese healthcare SMEs have relatively easy access to hospital and patient data for example in form of temporary GPU workstations in order to use images locally.

Preparing for a future of AI in healthcare, SMEs agreed on the continuing optimization of algorithms and of existing AI applications as well as the expansion to new application areas. New AI technologies need to be tracked and carefully introduced to the healthcare sector. German and Chinese interviewees plan to strengthen external collaborations but are following different strategies. In both countries, companies are collaborating with universities and research laboratories, when cooperating with external AI experts and software companies healthcare SMEs in China showed stronger activities. These identified strategic approaches show and approve the necessity of collaboration in the field of AI between all stakeholders to initiate and increase their efforts for a better transition from AI in the development phase to its application [28].

6 Conclusion, Limitations, and Outlook

This study concentrated on the adoption of AI in healthcare SMEs, which were identified as an organizational group with a less received focus in previous work. We contribute to current empirical research with a cross-national comparison of Germany and China. On the one hand, representatives of both countries underlined several advantages of the adoption like efficiency improvement or workload reduction of physicians. On the other hand, various thoughts are necessary regarding aspects like data quality as well as transparency and accountability to successfully proceed with the implementation of AI in healthcare organizations. Especially the German interviewees pointed out a stronger focus on the challenges within the adoption procedure and had concerns regarding legal guidelines and questions to be solved in the context of data access and transparency. In both countries interviewees are expecting a continuing trend within the upcoming years regarding the integration of AI in new areas and applications in healthcare, but also a better performance compared to the existing use of AI in applications. Chinese representatives gave insights in a stronger strategic focus on future research and development activities, whereas in Germany the improvement of AI transparency and interpretability is seen as a goal.

There are few limitations that need to be considered for the result interpretation and for upcoming research. 14 SMEs were equally distributed from China and Germany. This definitely gives valuable insights into the healthcare landscape and the scope of SMEs, but the sample size is not representative for both countries as a whole. The headquarters of the companies were located in southern Germany, mainly linked to the Medical Valley. In China, the selected SMEs stronger represent the eastern part, which is seen as economically more developed than the western part of the country [47].

Due to the COVID-19 pandemic all interviews were conducted online, some without video. The non-face-to-face format might have led to a different interview behaviour of the interviewees and influenced the interpretation of their answers without the ability to see the facial expressions and gestures during the interviews.

As a follow-up to this study, the sample size could be expanded regarding both countries and views of SMEs compared to those of traditional and established companies further explored. In addition, the investigation within other countries could follow the approach of Laï et al. [28] who concentrated on French health professionals instead of SME representatives or addresses AI adoption in other industries besides its presented influence in healthcare.

7 Acknowledgements

Bjoern M. Eskofier gratefully acknowledges the support of the German Research Foundation (DFG) within the framework of the Heisenberg professorship program (grant number ES 434/8-1).

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