ARTIFICIAL INTELLIGENCE IN AUGMENTATIVE AND ALTERNATIVE COMMUNICATION SYSTEMS - A LITERATURE-BASED ASSESSMENT AND IMPLICATIONS OF DIFFERENT CONVERSATION PHASES AND CONTEXTS

Research Paper

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Abstract

Even though AAC systems and corresponding AI approaches have been investigated within the extant research, they still show remarkable drawbacks, resulting in a low prevalence among speech-impaired individuals. As the suggestions and adaptions proposed by AI within AAC systems may show insufficiencies in certain situations (e.g., unreliable suggestions, low conversational rates, unauthentic adaptions towards users), we take an up-close look, especially at the conversation phases and contexts in which the supporting AI is applied. Therefore, we have conducted a systematic literature review as well as a literature analysis. Thereby, we could reveal that there are indeed several gaps within the extant research on AI regarding the coverage of the conversational context "informativeness" and the conversation phases "beginning" and "closing". To dismantle the existing communication barriers that speech-impaired individuals suffer from, several implications for investigating AI in the context of AAC systems are derived and proposed for future (IS) research.

Keywords: Augmentative and Alternative Communication Systems, Artificial Intelligence, Conversation Phases, Conversational Contexts, Systematic Literature Review.

1 Motivation

"Perhaps the single quality most central to humanness is the ability to exchange thoughts, ideas, and feelings with others" (Hourcade et al., 2004, p. 235). In this context, speech is seen as an individual's most important instrument to be in contact with its human surroundings (cf. Fritzell, 1996; Kane et al., 2017; Pollak and Gallagher, 1989). However, individuals that suffer from severe physical disabilities or brain injury are not able to control their oral-respiratory musculature sufficiently for speech (Allen, 2005; Vanderheiden, 1983). This restriction of verbal communication, and hence, the "separation from the mainstream of society" (Hourcade et al., 2004, p. 235) holds true for people with damages to the vocal tract or other impairments (e.g., aphasia, autism) affecting speech as well (Allen, 2005).

To get in exchange with their surroundings, speech-impaired individuals need to apply Augmentative and Alternative Communication (AAC) which combines strategies, symbols, and techniques to promote goal-directed communication (American Speech Language Hearing Association, 1991). AAC comprises different analogue forms of communication (i.a., sign language, picture boards). In the context of sign language, expressions are formed using mimics and gestures. But these expressions can easily be overlooked or misinterpreted when the interlocutors have little or no experience in sign language (Boyes-Braem et al., 1994). Compared to vocal language, sign language lacks expressiveness because it provides only a few prepositions and conjunctions. Furthermore, it contains no genus markers to differentiate between masculinum and femininum for nouns (Louis-Nouvertné, 2001).

To give individuals with speech impairments a voice and enable them to express themselves using vocal language, digital AAC solutions have emerged that enable the translation of an individual's intended meaning into speech and subsequent voice outputs (cf. Bradshaw, 2013). The positive influence of these voice-generating AAC systems on the interaction behaviour of speech-impaired individuals has already been proven in numerous studies (e.g., Brady, 2000; Desai et al., 2014; Schepis et al., 1996). Despite the positive influence and although these AAC systems manage to meet several design requirements *(see Section 2.2)*, they still show drawbacks that research has attempted to address by various Artificial Intelligence (AI) approaches (e.g., Dempster et al., 2010; Neamtu et al., 2019; Obiorah et al., 2021). While it is undeniable that these AI approaches could increase the practicability of AAC systems (e.g., Klauer et al., 2021; Laxmidas et al., 2021; Obiorah et al., 2021), these systems nevertheless have only a low prevalence among the target group as they still face different problems.

For example, AAC systems propose only low conversation rates as the suggestions generated, and the utterances composed by AI often do not fit the concrete situation in which the AAC user takes part. As a consequence of unreliable suggestions, speech-impaired individuals have to exert effort to produce an utterance or have to adjust the suggestions to generate an appropriate contribution to the conversation (e.g., Dempster et al., 2010; Laxmidas et al., 2021; Obiorah et al., 2021). The possibilities AI approaches propose concerning personalisation towards the user of the AAC system show limitations as well (e.g., within situation-depending adaptions of the speech output tonality). The adaptions proposed by the AI are often not perceived as authentic by the conversation participants given a certain situation because certain situational factors (e.g., time progression and changes of involvement and attitude towards a conversational topic) are not incorporated into the adaption (e.g., Ascari et al., 2020; Mills et al., 2014; Shen et al., 2022). Because the suggestions and adaptions proposed by AI approaches within AAC systems show insufficiencies in certain situations, this suggests that the AI approaches in particular need to be investigated and adapted concerning the conversations in which they are applied. Indeed, conversations are performed in different conversation phases ("beginning", "middle" and "closing" of a conversation) and within different contexts (e.g., formal conversations within meetings at the workplace vs. informal conversations with friends within spare-time activities).

So, while the beginning of a conversation with an acquaintance in an informal context does not require the assessment of the conversation partner (i.a., personality, attitudes, conversational behaviour), the conversational beginning with a business customer in a formal negotiation within a meeting requires the assessment of him or her. In the same vein, while the beginning of a conversation is comparably standardised (cf. Henne and Rehbock, 2012; Spiegel and Spranz-Fogasy, 2001), the middle of conversations may be more complex as the involved conversation participants may aim at diverging conversational goals, requiring mutual and coordinated conversational acting until a targeted and mutually accepted state of the conversation is reached. As can be concluded, the different conversation phases and conversational contexts consequently lead to different demands and requirements of a supporting AI approach that need to be met to comprehensively and optimally support a speech-impaired individual.

With the work at hand, we address these issues by conducting a systematic literature review (Cooper, 1988; Vom Brocke et al., 2015; Webster and Watson, 2002) to establish an initial basis for the underlying research topic and thus develop a deeper understanding of the research field of AI in the context of AAC systems as well as to identify existing research problems and gaps and justify the relevance of addressing them (Vom Brocke et al., 2015). In this context, we identify AI-based potentials in view of AAC systems and assign them to the phases "beginning", "middle" and "closing" (cf. Henne and Rehbock, 2012) of a conversation as well as to the two conversational contexts "socialness" and "informativeness" (cf. Bedrosian et al., 2003; Hoag et al., 2004; Todman and Alm, 1997). Against this background, the following two research questions (RQs) are posed: ***(RQ1)*** *Do the applications of Artificial Intelligence that are proposed within the extant research literature for AAC systems cover the conversation phases "beginning", "middle" and "closing" and the conversational contexts "socialness" and "informativeness" appropriately?* ***(RQ2)*** *What are possible implications for AI in the context of AAC systems regarding the consideration of conversation phases and conversational contexts?*

We contribute to the inclusion of speech-impaired individuals into societal life and accelerate the corresponding Information Systems (IS) research so that these individuals are proposed comprehensive and individualised AI-supported AAC. The remainder of this paper is structured as follows: Section 2 provides the theoretical background and the related work. In Section 3, we describe the procedure of the literature review and literature analysis. Afterwards, in Section 4, we present our results and discuss the reasonable implications of the research in Section 5. Finally, Section 6 draws an overall conclusion.

2 Conceptional Basics and Related Work

2.1 Conceptional Basics

To investigate the problems of current AI-based approaches within the context of AAC systems in more detail, we take an up-close look at the conversations in which AI is applied. In this context, extant communication research has investigated structures and components (i.e., communication activities, contents, sequences) within daily conversations. According to Henne and Rehbock (2012), a conversation can be structured into an opening, a middle and a closing part. Each of these conversation phases has specific goals and comprises individual communication activities the conversation participants need to perform (cf. Spiegel and Spranz-Fogasy, 2001). The opening part concerns, i.a., the recognition of incoming communication requests, the identification, assessment and greeting of the conversation partner as well as the introduction of the conversation topics (cf. Henne and Rehbock, 2012). The closing part deals with closing the conversation, thanking the conversation partners and farewelling them (cf. Schegloff and Sacks, 1973; Spiegel and Spranz-Fogasy, 2001). In comparison to the opening and closing part, the middle part aims to fulfil specific communication activities that are related to the conversation goal and the purpose framed within the opening part (Henne and Rehbock, 2012).

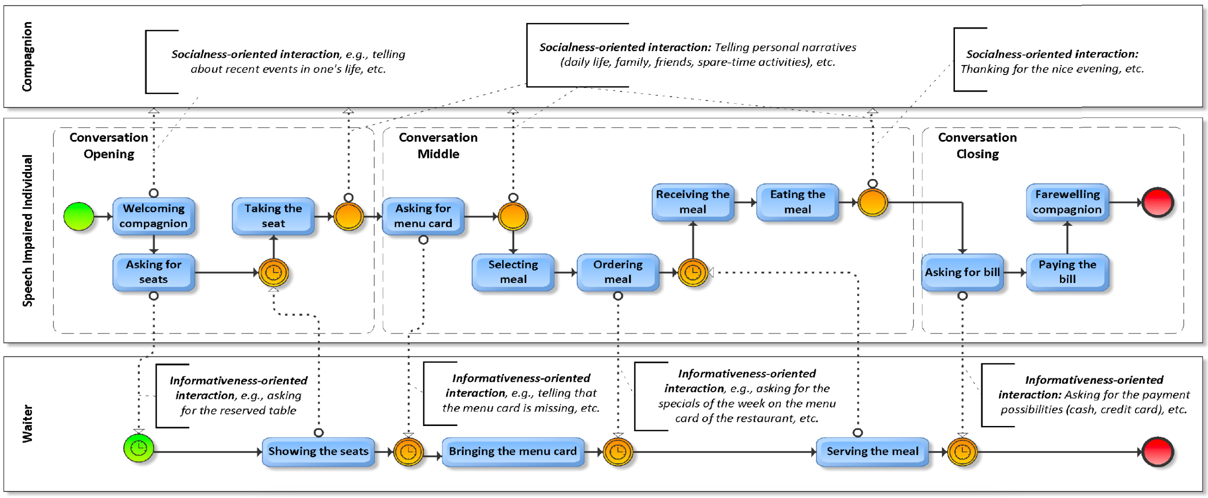

Figure 1. Illustration of different types of interactions (in particular "socialness-" and "informativeness"-oriented) in the example of visiting a restaurant with an acquaintance, own illustration related to Ehlich and Rehbein (1972) and Schindler (2013).

The conversation activities being performed within the respective conversation phases are further determined by different factors, i.e., the number of conversation participants involved (one-to-one conversations vs. group conversations) (Ehlich and Rehbein, 1972), the relationships that exist between the conversation partners (acquaintances vs. strangers) (Spiegel and Spranz-Fogasy, 2001) and the conversational context ("socialness"-oriented vs. "informativeness"-oriented conversations (cf. Bedrosian et al., 2003; Hoag et al., 2004; Todman and Alm, 1997)). Accordingly, group conversations require more complex activities to synchronise the conversation flow and the conversation utterances being exchanged. Further, interactions with friends or acquaintances, e.g., within a restaurant visit, are rather “socialness”-oriented and informal while the interactions with the waiter at the restaurant are rather “informativeness”-oriented and formal (cf. Ehlich and Rehbein, 1972; Schindler, 2013). As a consequence, humans communicate differently and apply different articulations depending on whom they interact with *(see Figure 1)*. Nonetheless, speech-impaired individuals lack the fundamental capability to apply vocal language and therefore need to apply Augmentative and Alternative Communication.

Augmentative and Alternative Communication encapsulates strategies, techniques, and tools that support individuals with speech impairments in expressing their thoughts, desires, feelings, and ideas (Hourcade et al., 2004). In this context, AAC systems can be described as VOCAs (Voice Output Communication Aids) or SGDs (Speech Generating Devices) providing speech-impaired individuals with the ability to express themselves using vocal language. Currently available high-tech AAC systems encompass the use of electronic devices (e.g., smartphones, tablet PCs) and the devices' built-in peripherals (e.g., camera, microphone) (e.g., Baldassarri et al., 2014; Laxmidas et al., 2021). The board within AAC systems contains the vocabulary the users can employ. To contribute utterances to conversations, users of AAC systems can either relate to pre-stored sentences (e.g., Alm and Higginbotham, 2008), can compose single words within the so-called speech line (Klauer et al., 2021) or can make use of keyboard capabilities and a combination of letters to express words and sentences (e.g., Kristensson et al., 2020). The utterance formed and to be spoken towards the conversation partner is then processed by the speech synthesising module that generates the voice output that is subsequently emitted towards the conversation partner by the loudspeaker of the device. This voice output can in turn be interpreted and reciprocated by the conversation partner so that the conversation can progress using mutual and coordinated utterances until a targeted state of the conversation is reached.

2.2 Design Requirements of AAC Systems

To be purposeful for speech-impaired individuals, research has investigated several design requirements for AAC systems. There have been considered general requirements, such as the support of multiple languages (e.g., Guasch et al., 2019; Kane et al., 2017), availability for different operating systems (e.g., iPad OS, Android) and devices (e.g., smartphones, tablet PCs) (e.g., Baldassarri et al., 2014; Dattilo et al., 2008), reliability and confidentiality of the AAC system concerning generated communication data (e.g., Dattilo et al., 2008; McNaughton and Bryen, 2007). Beyond that, an AAC system needs to propose a core vocabulary that enables users to exchange needs, wants and thoughts within various daily life situations (cf. McNaughton and Bryen, 2007; Van Tilborg and Deckers, 2016). In this connection, the AAC systems must offer a dynamic expansion of the vocabulary (e.g., Van Tilborg and Deckers, 2016; Wang et al., 2018). To open up the variability of speech, the storage of synonymous outputs for respective the same utterance needs to be enabled (Alm and Higginbotham, 2008). For individuals hindered to edit the vocabulary on their own because of severe cognitive disorders accompanying their speech impairment, family members, caregivers, and nursing staff need to be given access to the AAC system (Baldassarri et al., 2014). Cognitive disorders also require assigning pictograms to the respective utterances to support the understanding of the concept related to an utterance (e.g., Guasch et al., 2019; Klauer et al., 2021). To support efficiency in selecting vocabulary, it is necessary to propose means to structure the utterances, e.g., with topic- and concept-specific folders or grids (e.g., Klauer et al., 2021; Wang et al., 2018). Further, there are design requirements for the individualisation of the AAC system towards the users’ personalities. To customise the way an utterance is outputted, AAC systems propose the user means to adjust the speed and the volume of the voice output (e.g., via sliders in the GUI) (e.g., Arnott and Alm, 2013; Kane et al., 2017). In this vein, maintaining individual user profiles that include user-related preferences enables the customisation of the speech output (e.g., gendering the voice output, storing the user’s personal life history) (Alm and Higginbotham, 2008; Guasch et al., 2019).

Although these several design requirements have been investigated within the extant literature, AAC systems still show drawbacks, i.a., low communication rates (cf. Arnott and Alm, 2013; Kane et al., 2017; Klauer et al., 2021) and low user- and situation-specific individualisation (e.g., Arnott and Alm, 2013; Kane et al., 2017; Murphy, 2004; Van Tilborg and Deckers, 2016). Therefore, research has started to investigate the potentials of AI approaches within AAC systems.

2.3 AI Approaches and AI-based Potentials in the Context of AAC Systems

Artificial intelligence relates to the ability of a machine to apply characteristics of human intelligence to solve specific problems and adapt to changing environments (Boden, 2018). The capabilities of AI have recently been incorporated within AAC systems, leading to advances in the support of speech-impaired individuals. Corresponding AI approaches consider for example the user's past selection data, including the object of interest, time of use or, related GPS locations, to predict what a user wants to express in a specific context (e.g., Klauer et al., 2021; Neamtu et al., 2019; Obiorah et al., 2021). To further enhance the users' communication competency, approaches to model conversational topics that could be of interest in a conversation take advantage of Natural Language Generation (NLG) (e.g., Dempster et al., 2010; Vertanen, 2017). AI-based speech recognition and parsing of the interlocutors' verbal expressions propose need-fitting information that could improve both rate and relevancy of the utterances (e.g., Neamtu et al., 2019; Wisenburn and Higginbotham, 2009). Besides the consideration of the interlocutors' voice, facial features can be useful when retrieving relevant information regarding the conversation (e.g., Ascari et al., 2020; Kane et al., 2012).

As can be derived, there are AI approaches that can support speech-impaired individuals within AAC systems. Nevertheless, it remains unclear whether the conversation phases and conversational contexts have so far been sufficiently addressed. However, it is necessary to cover several conversation phases and conversational contexts to effectively reduce the communication gap speech-impaired individuals suffer from. Thus, within the research at hand, we conduct a differentiated investigation of the extant AI-based potentials and thereby aim to contribute to closing this communication gap.

3 Research Approach

3.1 Collection and Evaluation of the Literature

Within our investigation, we performed two systematic literature reviews (Cooper, 1988; Vom Brocke et al., 2015; Webster and Watson, 2002). With the **first** literature review, we aimed at identifying design requirements posed for AAC systems within the extant literature. Thereby, it could be revealed that, although several design requirements are being investigated, there are still drawbacks these AAC systems show, i.a., low communication rates (e.g., Arnott and Alm, 2013; Kane et al., 2017) and low user- and situation-specific individualisation (e.g., Arnott and Alm, 2013; Murphy, 2004; Van Tilborg and Deckers, 2016). To address these drawbacks, the prevailing research has proposed various AI approaches. Because these AAC systems nevertheless show only a low prevalence among speech-impaired individuals, with the **second** literature review, we focused on the AI approaches and AI-based potentials for AAC systems that are proposed within the extant research literature and that we subsequently aim to investigate in more detail regarding the conversation in which the AI is applied.

Considering the taxonomy of Cooper (1988), the focus of this literature review was to investigate the potentials of AI in the context of AAC systems. Thereby, we could identify that applying AI for supporting individuals suffering from speech impairments by means of AAC systems across different phases of a conversation and within different conversational contexts is yet an under-researched topic *(see Section 2.3)*. To address this gap, firstly we identified current AI approaches and corresponding potentials for AAC systems and, secondly within the analysis of the literature, assigned the identified AI-based potentials to the three conversation phases "beginning", "middle" and "closing" as well as to the two conversational context "informativeness" and "socialness". As the differentiated investigation of AI approaches and their potentials in the context of AAC systems has so far not been addressed sufficiently within the extant research, it is nonetheless essential in order to design and develop more suitable AI approaches for AAC systems and their users.

The literature review followed a five-step procedure (Cooper and Hedges, 1994): **(I)** Problem Statement, **(II)** Collection of the Data, **(III)** Data Evaluation, **(IV)** Analysis and Interpretation of the Data, and **(V)** Presentation of the Results. The problem statement has been introduced above in *Sections 1, 2.2 and 2.3*, while the remaining aspects **(II)** - **(V)** are described in detail in the upcoming sections. At first, a topic-based search was performed to query scholarly databases (Vom Brocke et al., 2009; Webster and Watson, 2002). The following databases were analysed: ACM Digital Library, AISeL, Emerald Insight, Google Scholar, IEEE Xplore, SpringerLink, Science Direct and Web of Science. These databases cover leading journals of the IS discipline, proceedings of highly renowned IS conferences, as well as technical reports and dissertations. By means of these selected databases, we not only cover the extant IS research but also research communities that explicitly address the investigation of AAC systems and their support potentials for speech-impaired individuals (e.g., the "Augmentative and Alternative Communication" Journal within ScienceDirect). Next, by following an iterative refinement process (cf. Kitchenham et al., 2009; Wohlin et al., 2012), we derived keywords for our topic-based search which focuses on AI applications and AI-based potentials to support speech-impaired individuals by means of AAC systems. In general, there are numerous techniques that can potentially be applied in the realm of AI (e.g., for artificial neural networks: convolutional neural network or backpropagation neural network). Since it is difficult to cover all the specific AI techniques within the literature search, we took an initial look at the extant literature on AI in the context of AAC. Thereby, we could reveal that these papers also relate to the categories of AI techniques (e.g., "machine learning", "deep learning", "supervised learning", "unsupervised learning"). Thus, we applied these and additionally "AI" and "artificial intelligence" as keywords to cover the AI aspect within the literature collection. In the context of VOCAs and SGDs that we focused on as solutions for supporting people with speech impairments, it could be revealed that the relevant literature persistently referred to those in connection with the term "augmentative and alternative communication" or the abbreviation "AAC". Overall, the following keywords, and combinations of them, were therefore applied: "augmentative and alternative communication", "AAC", "artificial intelligence", "AI", "machine learning", "supervised learning", "unsupervised learning" and "deep learning". As a result of this literature search procedure, **107 papers** could be derived.

To assess the appropriateness of these 107 publications, we first scanned the titles of the papers. If the title hinted at the application of AI in the context of AAC to support speech-impaired individuals, in the second step, we read the abstract and the conclusion of the respective paper to verify its appropriateness. Regarding the purpose of our research, we applied the following preconditions within the literature assessment: ***(1)*** *Does the publication deal with the application of AI in the context of AAC?* ***(2)*** *Does the publication reveal how these AI applications propose support for individuals suffering from a speech impairment?* ***(3)*** *Does the publication limit its application to the end device of the user and does not include further external devices, hindering the portability of the AAC systems within daily life situations, e.g., EEG sensors, sensors for acquisition of nasal pressure?* (cf. Elsahar et al., 2019).

After applying these inclusion criteria to the identified literature, 25 papers remained. For these **25 papers**, we additionally and iteratively applied backward and forward searches (cf. Webster and Watson, 2002). This resulted in **three** additional references that could meet the above-mentioned inclusion criteria. Regarding the distribution of the finally resulting **28 papers** used for the upcoming analysis across the searched databases, we found the following (with duplicates and papers not in the English language already sorted out): **14** references were extracted via Google Scholar, **three** via SpringerLink, **three** via Web of Science**, two** via Science Direct, **two** via the ACM Digital Library, **two** via IEEE Xplore, **one** via Emerald Insight and **one** via the AISeL.

3.2 Literature Analysis

After evaluating the literature collection, we analysed the relevant publications. Here, qualitative content analysis (cf. Mayring, 2004) was applied, which helps to filter out those fragments of information from larger texts that are suitable for answering the RQs.

3.2.1 Deriving the AI-based Potentials in the context of AAC Systems

The AI-based potentials being harnessed in the context of AAC systems were derived as follows: First, the publications were screened regarding any text statement that hinted at a realisable benefit (potential) of AI approaches to support speech-impaired individuals in the course of a conversation by means of an AAC system. On the one hand, some papers directly related to the potentials of applying the described

AI approaches, i.a., within the problem statements or the application and evaluation of the AI approaches (e.g., increase the speed of response or the individualisation of conversation contributions). On the other hand, in cases when there was no AI-based potential immediately observable, we related to the notion of key performance indicators in the context of AAC systems (e.g., number of clicks to produce a conversation contribution, flexibility of the utterances) and to the already derived potentials. In this way, we could derive a broad range of potentials for AI approaches for AAC systems. For the subsequent assignment to conversation phases and conversational contexts, we aimed to derive a manageable number of categories. Therefore, an abstraction of the AI-based potentials into coherent categories was carried out (cf. Mayring, 2004). Based on the attention and importance received within the literature, and led by the entities and structures that constitute a conversation (cf. Henne and Rehbock, 2012; Schank and Schoenthal, 2016), in particular, four categories could be derived *(see Section 4)*.

3.2.2 Assigning AI-based Potentials to Conversation Phases and Conversational Contexts

Subsequently, we aimed at assigning the identified AI-based potentials to the phases “beginning”, “middle” and “closing” as well as to the conversational contexts “informativeness” and “socialness”. The following assignment criteria could be derived from the extant literature and were applied: The publications were screened regarding any text statement that hinted at the phases “beginning”, “middle” and “closing” of a conversation or the conversational context “informativeness” and “socialness”. Hereby, the text statements were observed whether communication activities that are commonly performed within the respective phases are described within the paper (e.g., recognition of incoming communication requests, the identification, assessment and greeting of the conversation partner as well as the introduction of the topics of the conversation in the “beginning”, recognition of the fulfilment of the conversational goals, closing the conversation, thanking the involved conversation partners and farewelling them in the “closing”). Regarding “informativeness” and “socialness”, the assignments related to the description of the situation in which the conversations in the respective papers were performed. Regarding the criteria for an assignment, “informativeness”-oriented interactions are rather formal and aim at conciseness, clarity and relevance of the contents (cf. Bedrosian et al., 2003; Hoag et al., 2004). In comparison, “socialness”-oriented interactions are rather informal, aim at keeping pace with the speed of the conversational flow and are rather observed in social contexts (cf. Todman and Alm, 1997). In those cases when none of the conversation phases or conversational contexts could be observed within the respective paper, an assignment to “Not specified” was applied. If any assignment faced ambiguities, these were cleared within discussions and justifications among the involved researchers.

4 Results of the Literature Analysis

To effectively synthesise the extant research literature, we derived four coherent categories, representing the potentials of AI in the context of AAC systems, by applying inductive category development (Mayring, 2004). These categories represent the potentials of AI for AAC systems, distinguished by four dimensions: *1. Formal Course of a Conversation, 2. Natural Context Factors, 3. Interlocutor, and 4. Speech-Impaired Individual (i.e., the user of the AAC system).* In the following, exemplary potentials of the derived categories are presented.

Maintaining the Formal Course of a Conversation

The first category deals with the potential of AI in terms of the formal course of a conversation. The main objective is to ensure the grammatical correctness of the utterances, supporting their comprehensiveness and thus maintaining the overall conversation course. From the perspective of Natural Language Processing (NLP), speech errors from speech-impaired individuals can be interpreted as grammatical errors at the morphological and syntactic levels. Therefore, Park et al. (2021) applied neural Grammatical Error Correction (GEC) to ensure the formal correctness of the utterances. More precisely, they applied a deep learning-based speech-to-text approach, taking the voice of the user as input and converting it into text. Subsequently, the GEC algorithm revises various linguistic errors to replace missing or wrong words and to enable the users to practice the vocal language. To support users with autism, Hervás et al. (2020) proposed an application to automatically compose messages based on pictograms that include AI predictive capabilities. Since predictive systems and orthographic correctors can sometimes persistently provide incorrect or undesirable options, the authors implemented a functionality whereby users can correct messages using NLP-based part-of-speech decomposition, thereby ensuring the semantic and formal correctness of the message.

Incorporating Natural Context Factors

To further support AAC systems through the potential of AI, researchers attempted to incorporate natural context factors to improve the proposed user responses by recommending situationally appropriate utterances. In this regard, numerous scholars have recognised the importance of environmental-related (e.g., GPS coordinates) or time-related (e.g., daytime) information (e.g., Klauer et al., 2021; Neamtu et al., 2019; Reddington and Tintarev, 2011; Waller, 2019).

In this context, Emil et al. (2020) developed an AI approach facilitating communication by analysing users' past selection data, including the object of interest, time of use, touch duration, GPS location, and pictogram location on the screen. Similar to this, Laxmidas et al. (2021) proposed an approach including a recommendation engine based on nearest-neighbour clustering. Each time an utterance is selected, the engine updates its internal ranking and takes into account the given time of the day and the number of selections. Subsequently, these features are partitioned into ideal clusters so that an optimal collection of relevant utterances is available for any given time of day. Also, Neamatu et al. (2019) turned their attention to the use of AI to make context-based recommendations for utterances. By analysing historical usage data (e.g., the object of interest, time of usage, GPS data, touch time) the developed machine learning algorithm predicts what a person with a speech impairment may want to express in a specific context. Further, an approach to model conversational topics that would be of interest in social conversations is presented by Dempster et al. (2010), which takes advantage of NLG to automatically create and adopt a user-specific ontology (cf. Karakatsiotis et al., 2008). To do so, several contextual information (location, time) are turned into useful conversational utterances through a template-driven utterance generation system. In addition to looking at contextual factors in general, several investigations took a step further and tried to determine how contextual factors can support specific daily activities. Obiorah et al. (2021) focused on supporting a specific leisure activity (dining in a certain restaurant) by facilitating dynamic language productions by incorporating location-related web content to support the comprehension of novel vocabulary. Similarly, Tintarev et al. (2016) focused on supporting children with complex communication needs in school to facilitate interactive narratives about personal experiences. To achieve this, the authors developed an AI-based clustering algorithm considering several locations, time and voice recording data to create concrete utterances, reflecting holistic personal narratives. To personalise the respective utterances, the approach identifies different event boundaries in terms of location changes and events specified in the children's timetables.

Tailoring towards the Interlocutor

Apart from the consideration of natural context factors such as geolocation and time of day, consideration of the interlocutor has also gained attention in the research field of AAC. In this regard, the approaches to integrate the interlocutor can be divided into two areas - speech recognition and image recognition - based on the technology used.

Wisenburn and Higginbotham (2009) demonstrated a computerised communication program utilising an NLP strategy consisting of speech recognition and a parser that proposes utterances incorporating the noun phrases spoken by the interlocutor as modular speech keys. In addition, Neamtu et al. (2019) enable speech-impaired individuals to respond more quickly by integrating a natural language conversation feature, which continuously listens to the surroundings and searches for specific trigger words and activates appropriate utterances. Therefore, the obstacle to conversation initiation and thus the communication gap are reduced. Further, the authors implemented a natural language sentence classifier to examine the raised question of the interlocutor and to classify whether the question is dichotomous. If so, the AAC system will solely present the answers of "Yes" and "No" to further enhance the communication exchange. Similarly, Emil et al. (2020) could reduce the time and effort required to communicate using a text-to-speech module in conjunction with an NLP-based classifier. The algorithm detects specific questions and presents the most relevant utterances to users based on the interlocutors' statements. In contrast, Vertanen (2017) developed an approach to initially extract the mentioned conversation topics and subsequently generate holistic utterances by using a neural network specifically tuned to the conversation topic. In this way, the cohesion between individual parts of the conversation can be increased, resulting in a reduction of the communication gap.

Besides the consideration of the interlocutors' voice, also facial features or gestures can be useful when retrieving relevant information regarding the course of the conversation. Accordingly, Kane et al. (2012) developed an approach to generate person-associated utterances based on facial image recognition of the interlocutor, resulting in a more personalised and convenient system. Ascari et al. (2020) further applied AI in the form of a gesture recognition classification algorithm to identify non-verbal expressions of the interlocutor and transform them into associated emotions. Subsequently, they will be included in the generation of the users' responses, allowing them to respond to the mood or emotions of the interlocutor and thus strengthen their ability to communicate.

Tailoring towards the Speech-Impaired Individual (AAC System User)

In addition, numerous researchers have harnessed the potential of AI to better tailor the conversation towards the user (e.g., characteristics, attitudes and preferences of the user). Shen et al. (2022) proposed a multi-turn dialogue system that applies a language model with bag-of-keywords and personality-related information to generate high-quality responses based on keyword entries. By the generation of meaningful utterances with very little user input, additional keystrokes were saved, leading to a significant reduction in the communication gap. Further, Mancilla et al. (2015) developed an ontology personalisation approach for an AAC system, which automatically extends a given domain ontology into a user-related one, including user-specific information. By including personal information in the communication process, the message quality improves as it becomes more complete and personal. According to Hernández et al. (2014), user behaviour is essential to establish personalised recommendations. Thus, the authors implemented a memory-based recommender system that tracks users by user archetypes, representing their behaviour patterns, goals and needs. Subsequently, the archetypes are used in conjunction with AI and statistical methods to predict and suggest need-fitted utterances. Further, Heo and Kang (2019) proposed a system to incorporate user-related information by applying a slot-filling method. By employing decision trees, it automatically learns slot priority strategies to enable the efficient selection of information for the user and thus an efficient way to prevent unnecessary inputs and minimise the number of keystrokes. Another method for integrating user-related information by generating context-related vocabulary from photographs of personally relevant events is presented by De Vargas and Moffatt (2021), who aimed at supporting people with speech impairments in recounting their past experiences. Here, NLP-based photo-to-story vocabulary generation reduced irritation and navigation errors and generated improved lexical retrieval during activity retelling. Johnson et al. (2020) demonstrated the usage of various sensors for measuring the voice and video recordings of non-verbal users. By using speech and image recognition, the user's moods, emotions and sounds can be measured and assigned to different categories (e.g., laughter, crying, or protest), thereby clarifying the underlying intention and supporting the user's expressiveness. Finally, as stated by Mills et al. (2014), several individuals suffering from speech impairment use the same synthetic voice, diminishing their expressiveness. To enable a more personalised voice, the authors developed an approach that extracts prosodic properties from the target talker's voice and applies these features to a surrogate talker's database, generating a synthetic voice with the vocal identity of the target talker and the clarity of the surrogate talker.

5 Discussion and Future Research

To identify existing gaps in the coverage of AI-based potentials concerning the conversational phases and contexts and thus deduce related research prospects, the AI potentials were further assigned to the appropriate conversation phases and contexts as described in Section 3.2.2. The respective assignments are shown in Table 1.

Authors / Publications	AI-based Potentials of AAC Systems				Conversation Contexts			Conversation Phases			
	Maintaining the Formal Course of a Conversation	Incorporating Natural Context Factors	Tailoring towards the Interlocutor	Tailoring towards the Speech Impaired	Socialn.	Inform.	Not Spec.	Beg.	Mid.	Clos.	Not Spec.
Ascari et al. (2020)			X				X				X
Dempster et al. (2010)		X	X	X	X				X		
De Vargas and Moffatt (2021)		X		X	X				X		
Emil et al. (2020)		X	X	X			X		X		
Heo and Kang (2019)				X			X				X
Hernández et al. (2014)				X	X						X
Hervás et al. (2020)	X			X		X					X
Hossain et al. (2018)		X					X				X
Johnson et al. (2020)				X	X				X		
Kane et al. (2012)		X			X						X
Klauer et al. (2021)		X					X				X
Kristensson et al. (2020)		X				X					X
Laxmidas et al. (2021)		X		X			X				X
Li et al. (2022)				X			X				X
Mancilla et al. (2015)		X		X	X				X		
Mills et al. (2014)				X			X				X
Neamtu et al. (2019)		X	X	X	X			X	X		
Obiorah et al. (2021)		X	X			X		X	X		
Park et al. (2021)	X	X		X			X		X		
Reddington and Tintarev (2011)		X			X				X		
Roy et al. (2021)	X		X	X			X	X	X		
Shen et al. (2022)		X		X	X				X		
Tintarev et al. (2016)		X		X	X						X
Vertanen (2017)			X				X		X		
Waller et al. (2013)				X	X				X		
Waller (2019)		X	X		X				X		
Wandmacher et al. (2007)		X					X				X
Wisenburn and Higginbotham (2009)			X		X				X		

Explanation of the Abbreviations: *Socialn.: Socialness, Inform.: Informativeness; Beg.: Beginning; Mid.: Middle; Clos.: Closing; Not Spec.: Not Specified.*

Table 1. Assignment of AI-related potentials to conversation phases and conversational contexts.

The general picture that emerges from the analysis is that some studies have already addressed specific contexts and phases of conversations. However, significant gaps in the literature could be revealed, which indicate shortcomings in the research on the examined subject of AAC and AI. To guide research into the future, we derived several implications for research below.

5.1 Implications for Future Research

The findings deduced from the assignment of the AI-based potentials to the respective conversation phases and conversational contexts are intended to help researchers and practitioners to make sense of the accumulated knowledge in this emerging research field. Based thereon, we discuss implications concerning the observations throughout this investigation and outline novel directions for future research that may yield promising potentials in the field of AAC.

First, as a cursory glance at Table 1 reveals, there is no prevailing research that leverages the potentials of all derived categories to support speech-impaired individuals. However, to support communication holistically using an AAC system, the consideration of all conversation-related dimensions (categories) and thus the use of their associated potentials is indispensable. Thus, studies considering all relevant dimensions of a conversation simultaneously could be promising avenues for further research.

- The prevalent literature on the first category is sparse, with only three articles specifically addressing the use of AI to maintain a formal course within a conversation. In comparison, 17 articles deal with the integration of natural context factors as well as nine and 17 articles deal with the consideration of the conversation partner and the speech-impaired individual, respectively. This leads to the assumption, that there is a necessity for research concerning maintaining the formal course of the conversation by means of tailored AI approaches. In this respect, additionally to neural GEC, word prediction engines could be leveraged to influence the choices of spell checkers or to automatically correct minor spelling errors. Moreover, prediction engines that use syntactic or semantic components could similarly be used for grammar correction and disambiguation of meaning. For example, Widgit's Communicate software (Widgit, 2022) uses syntactic disambiguation to provide the appropriate symbol when an ambiguous word such as "can" occurs in a sentence. In general, probability-based prediction engines can be used in many situations where textual ambiguity exists, and support both conversational comprehension and users' communicative competence.

- Moreover, AI holds several potentials for text simplification and summarisation and thus supporting the maintenance of the formal course of conversation. Text simplification converts the associated text message into simpler sentence structures and vocabulary while retaining the meaning of the original (Al-Thanyyan and Azmi, 2021). This could also support the formal course of the conversation by breaking down more complex issues into simpler elements of communication, and thus reducing the likelihood of errors.
- Similar to text simplification, text summarisation aims to provide a brief overview of what is contained within large texts. Using an automatic summarisation approach, particularly important sentences in a document can be identified and included in the summary (Adhikari, 2020). Although comparable technologies are occasionally used for AAC systems (e.g., Obiorah et al., 2021), the potential of automatic text summarisation has yet to be exhausted. In this way, complex text messages could be simplified for individuals with cognitive-linguistic challenges. Newspaper or magazine articles, website content, or emails could be automatically processed and inserted into the AAC system to transform them into modules for expressive communication. With a simplified and appropriately segmented set of text modules, the user could select from these to discuss current events or personal narratives with grammatically and orthographically correct sentences.

Second, the consideration of conversational contexts is worth mentioning. As previously indicated, considering specific conversational contexts is one way to address the associated requirements (e.g., formal vs. informal) to specifically support the conversational process. However, as Table 1 reveals, solely three articles refer to the conversational context of "informativeness", while 13 articles take into account the conversational context of "socialness". Since the differentiation between these conversational contexts is indispensable to holistically support AAC-based communication *(see Sections 1 and 2.1)* and thus achieve a high level of communication competence in speech-impaired individuals, future research will need to shed light on how the conversational contexts can be supported by appropriate AI methods. Especially concerning the context of "informativeness", our results implicate research gaps, since the prevailing literature to date mainly focuses on the context of "socialness".

- Since "informativeness"-oriented communication is more concerned with the formal exchange of relevant information that focuses on conciseness, clarity, and relevance of content rather than the speed of exchange as in "socialness"-oriented communication (cf. Bedrosian et al., 2003; Hoag et al., 2004), "informativeness"-oriented communication aims at a holistic view of a topic, including the coverage of all topic-specific relationships. In contrast to "socialness"-oriented conversations, the focus is thus mainly on the meticulous elaboration of a specific topic and less on the superficial but more flexible coverage of a broad spectrum of differentiated topics.
- One conceivable approach for the holistic mapping of a discourse domain is the AI-based generation of an ontology that can be applied to map all topic-related concepts and their relationships. Ontologies model particular knowledge through a representative vocabulary determined by the formal definition of a set of concepts associated with a particular domain and the meta-relationships between them (Mancilla et al., 2015). In this way, criteria of "informativeness"-oriented communication such as clarity, coherence, and extensibility are further met (Gruber, 1995). To enable the holistic coverage of a conversation topic with all associated concepts, deep learning approaches (e.g., neural networks) can be applied in conjunction to dynamically identify and integrate topic-relevant concepts. Once a specific topic has been identified, probabilistic neural networks can allocate (potentially)

relevant concepts and dynamically extend the ontology with the topic-specific concepts. Therefore, semantically related concepts in various degrees of detail can be identified, resulting in a holistic coverage of the discussed topic and thus enabling, e.g., the formation of logical conversation chains supporting the formal exchange of information. As an example, when ordering a dish in a restaurant *(see Figure 1, Section 2.1)*, the user would also like to receive information about certain aspects that might be relevant to ordering the dish. If the user wants to ask about the origin of certain ingredients or possible allergens, the relevant topic-specific concepts must be available within the ontology. To achieve the dynamic extension of the given ontology, the associated concepts (e.g., the origin of specific ingredients) could be determined by a neural network and dynamically integrated into the ontology. By dynamically integrating topic-specific concepts, all relevant facets of a conversation can be taken into account, ensuring conciseness as well as the relevance of the respective content on the one hand and supporting clarity through a logical structure of the topics on the other.

- In this vein, studies additionally have to examine which event boundaries can be defined to dynamically switch between the conversational contexts to adapt the proposed utterances in a target-oriented way. Automatic speech recognition could be utilised to analyse the spoken words of the interlocutor regarding specific keywords to determine whether a communication shifts from "socialness" to “informativeness”. If a shift in the communication context is identified, the generation of utterances can be specifically geared to the requirements of the currently identified context, thereby increasing both the prospect of conversational success and the conversational competence of the user.

Third, in view of the conversation phases, each phase has to meet specific goals and therefore comprise individual communication activities the conversation participants need to perform *(see Section 2.1)*. Taking into account the assignment of the AI-based potentials to the respective communication phases, it becomes apparent, that the middle part is densely covered (15 articles), while the opening part (three articles) and the closing part (null articles) are not sufficiently considered yet. Nonetheless, since each conversation phase is associated with specific activities such as recognising incoming communication requests or closing the conversation by thanking the interlocutors, the consideration of each conversation phase and its associated requirements is essential to support a conversation holistically.

- In view of the conversation initiation, image recognition techniques and deep learning-based computer vision propose promising potentials. In this context, action and event recognition could identify an emerging conversation beginning by analysing, from a sequence of images, different actions that a human performs (Leo et al., 2018). Common examples of actions are, e.g., “answering the phone” or “shaking hands”, but also facial actions like “smiling” or “crying”. By identifying certain actions that indicate an upcoming conversation situation (e.g., a greeting gesture such as waving), a conversation situation could be initiated, whereupon the corresponding utterances would be suggested automatically. For illustration purposes, if a speech-impaired user enters a restaurant and is guided to his seat by a waiter, the AAC system could automatically identify, based on the waiter's gesture, that the user is guided to take a seat. Accordingly, the system can generate appropriate utterances that support the respective conversation situation and thus enable the generation of targeted utterances. Likewise, the facial expression of the conversation partner could be included in the automated adaptation of the vocabulary. Thus, in the case of an angry interlocutor, positively connotated vocabulary could be used to appease in.
- In the context of conversation closing, the focus is on farewelling the interlocutor (cf. Schegloff and Sacks, 1973; Spiegel and Spranz-Fogasy, 2001). Thereby, deep learning-based computer vision approaches could be used to enable automated recognition of the closing of the conversation by identifying gestures of farewell and adapting the proposed utterances accordingly. Further potential in the conversation phase could be represented by the automated evaluation of the conversation, the verification of the achievement of conversation goals, and the extraction and evaluation of discussed conversation topics. In this context, machine learning approaches such as automatic topic extraction (cf. Jelodar et al., 2019) could be used to extract the discussed topics and subsequently have them evaluated by the user. If the user rates a topic positively, it can be prioritised in the automated identification of future conversation topics concerning upcoming conversations.

Overall, our results emphasise that AI techniques are ubiquitous in current AAC technologies and propose great potentials for development in the future. Therefore, we encourage research to address the consideration of phase- and context-specific requirements of an AAC conversation to develop appropriate techniques to support speech-impaired individuals and thus better integrate them into social life.

5.2 Limitations

The investigation at hand has several limitations. Although we conducted a broad and structured database search covering major outlets, other researchers might have uncovered additional search terms and additional relevant papers. Yet, this structured literature review allows for a transparent, replicable, and comprehensive overview of AI-based potentials in the context of AAC systems. The assignments of the derived AI-based potentials to conversation phases and conversational contexts bear to a certain extent subjectivity. However, several assignments were performed by three researchers individually. In case of disagreements, the article in question was analysed by a fourth researcher, followed by a discussion until a consensus was reached. Despite these limitations, we are confident that our findings help to get a first overview and a better understanding of the current AI approaches in the context of AAC systems and the insufficiencies of the AI decisions that can be related to the underlying conversations.

6 Conclusion

Digital systems of Augmentative and Alternative Communication for supporting speech-impaired individuals have gained tremendous importance as a means of the inclusion of speech-impaired individuals into societal life. Although the extant research has investigated several design requirements and AI approaches, there are certain circumstances where AAC systems deduce recommendations and apply adaptions that are insufficient given the specific situation in which they are applied. This is due to the divergent requirements imposed by the conversation context (e.g., formal vs. informal conversations) and its structure (e.g., conversation phases). Thus, as the AI approaches may need to be adapted concerning the conversations in which they are applied, we took an up-close look thereon within our investigation.

To establish a first basis for the underlying research topic and to develop a deeper understanding of the research field of AI in the context of AAC systems, we have therefore conducted a systematic literature review *(see Section 3)*. In this way, we have derived corresponding AI approaches and deduced related AI-based potentials. For their subsequent assignment to conversation phases and conversational contexts, we could derive four categories that are based on the attention and importance they have received within the extant literature and are additionally led by the entities and structures that constitute a conversation (e.g., conversational partners, the course of the conversation). Subsequently, based on the determinants of the phases and contexts that are described in the corresponding literature, we have assigned the categories of AI-based potentials to the conversation phases “beginning“, “middle“, “closing“ and to the two conversational contexts “informativeness“ and “socialness“. As this assignment revealed, there are indeed several gaps within the extant research on AI regarding the coverage of the conversational context “informativeness” and the conversation phases “beginning” and “closing” *(see RQ1)*.

To this extent, this paper proposes several contributions. First, based on the extant literature, it provides a comprehensive and structured overview of AI-based potentials in the context of AAC systems. Moreover, we have consolidated these AI-based potentials into an abstraction of four coherent categories *(see Section 4)* and could establish synergies of these research areas. Second, our results propose possibilities for AI research to investigate the identified AI-based potentials within conversation phases and conversational contexts that have received less attention yet. Based on the contributions of the work at hand, AI approaches that are established within other fields (e.g., within voice assistants for voice commerce, e.g., Reinkemeier et al., 2022) and current generative AI-based language models could be investigated in specific for the case of AAC systems. To guide future research, we contribute several implications for investigating AI in the context of AAC systems, especially regarding the conversation in which the supporting AI is applied *(see RQ2)*. We hope future IS research strives to address the revealed gaps to dismantle communication barriers speech-impaired individuals suffer from.

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