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SURVEY

Defining, Designing and Distinguishing Artificial Companions: A Systematic Literature Review

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Abstract

The present study systematically reviewed scientific literature addressing the concept of artificial companions (ACs). The dataset, which encompasses 22 years of research, was drawn from multiple interdisciplinary sources and resulted in the development of an interdisciplinary definition of the AC concept. This definition consists of two key characteristics: adaptivity and engagement, the hallmarks of ACs to form emotional bonds and long-term relationships with users. The study also analyzed various design properties associated with ACs, categorized into five groups: adaptivity to the user, adaptivity to the usage context, engagement-facilitating behavior, the agent's personality, and its appearance. In the third part, the study explored AC scenarios and identified roles that ACs can perform with their associated competencies, user groups, and application areas. The findings of this study are seen as a proposal for future empirical research to test what features in communication and interaction design play a crucial role in shaping the perception of an agent as an AC.

Keywords Artificial companions · Systematic literature review · Human–machine-communication · Human–machine-interaction · Companion-paradigm · Social design

1 Introduction

1.1 Problem

Within the last years, the idea of developing a technology that is a reliable partner or an empathic friend became popular - see, for instance, several science-fiction productions, such as Robot and Frank (2012), Her (2013), Big Hero 6 (2014), Next Gen (2018), Ron's Gone Wrong (2021), or Finch (2021). Likewise, we see a broad number of research projects aiming to develop companion systems, e.g., projects as SYMPARTNER [1], CARING [2], or CompanionAble [3] as well as robots like Arash [4], Emobie [5], R1 [6], Reeti [7]. At the same time, consumer products labelled as companions are entering the market—like ElliQ,[1] Gatebox,[2] Moxi,[3] Qooboo,[4] Replika,[5] or Zenbo Junior.[6] These examples show that the idea of an artificial companion seems to be an enduringly pursued concept in pop culture, economy and science. Nevertheless, it is not easy to say what distinguishes an artificial companion from other social technology. Hug [8] recently examined the ambiguous use of the companion term. In addition to that, Böhle and Bopp [9] demonstrate how even scholars struggle to derive a coherent companion description within their research field. This uncertainty could be due to the various interdisciplinary approaches [8–14] that have not yet been systematically brought together. Hence, we see the problem that there is no common denominator for what we mean when we call an agent an artificial companion (AC, plural ACs) (RQ1), what this implies for the agent's design (RQ2), and how we can differentiate efforts in this area (RQ3).

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1 https://elliq.com.
2 https://gatebox.ai/en.
3 https://embodied.com.
4 https://qoobo.info/index-en.
5 https://replika.com.
6 https://zenbo.asus.com.

1.2 Related Work and Motivation

Looking at previous research, two things, in particular, stand out: Firstly, some papers understand ACs as a vision for progressive human–machine interaction (e.g., [8–10, 15–17]). This vision is associated with a mission or research agenda aiming form long-term relationships and resilient human–machine teams. To realize this vision, a large group of papers addresses central properties of an AC (e.g., [11, 13, 18–23]), the technical realization (e.g., [24–26]), or delivers empirical results on the effects of the interaction between humans and ACs (e.g., [27–30]). Also, there exist comprehensive reviews the towards needs of different user groups and available solutions that structure their argumentation according to relevant application areas (e.g., [9, 31]), or broader design guidelines (e.g., [32–34]). We would like to tie in with these previous findings by pursuing three objectives:

(1) Deriving an integrative AC definition: We conducted a literature review on a large number of papers (n = 540) systematically identified and extended by an additional sample of relevant work. By applying a systematic approach, we intend to reduce the risk of researcher bias, as all papers were blindly screened and only selected if they extensively discussed AC characteristics. In this context, extensively refers to a quantitative assessment in the paper selection. As a result, papers comprising a larger number of properties and thus (supposedly) dealing more comprehensively with the AC concept were preferred over papers discussing comparatively fewer design aspects. Most of the existing ACs conceptualizations base their findings on theoretical considerations (e.g., [8, 21]) or own empirical studies within a specific research project (e.g., [4, 5, 9, 13, 28, 29, 35]). Methodologically, the available literature reviews pursue defining ACs either non-systematically (e.g., [11, 19, 32]) or align their argumentation to a set application area (e.g., [17, 31, 33]). Our findings largely benefited from this previous work, and to that, we added value by analyzing given conceptualization independently and integrating these into the here suggested companion understanding. Furthermore, through the blind review and selection process, research articles from various disciplines are evenly included - whether they originate from technical or social sciences or if they reasoned their arguments on empirical research towards a dedicated application area or more general theoretical considerations.

(2) Compiling an AC's communication and interaction qualities: In the theoretical discussion on ACs, we constantly noticed wordings referring to the user's perception. For example, Turkle [16] describes ACs as artefacts "that would cause people to experience them as having subjectivities that are worth engaging with" (p. 150). Biundo et al. [11] speak of "appearing as 'Companions"' (p. 11) and assume that the realization of companion features will lead to technical systems "being perceived and accepted as competent and empathetic assistants" (p. 17). Danilava et al. [21] propose a list of requirements "that allow an artificial agent to be regarded as an Artificial Conversational Companion" (p. 288). Similarly, Dario et al. [10] raise several questions, such as "which features of living beings would we like to see in our robot companions?" (p. 49).

Such statements brought us to consider that building an AC depends on the user's perception. For example, think of two smart home assistants, both are (functionally) useful to their users to the same degree, but only one is referred to as a companion by the user. We assume that the difference between the two agents lies in the way they communicate and interact with their users. Accordingly, our overall research is motivated by the assumption that an agent's communication and interaction design impact the perception as a companion. However, to test this guiding hypothesis, we first need to understand what features are associated with an AC, which motivates the presented study. With this in mind, we analyze AC designs in this review and sort properties that are commonly discussed in the context of AC development. To the best of our knowledge, we are the first to conduct a systematic review of over 22 years of research focusing on an AC's communication and interaction qualities. Although, we have to refer to the work of [5, 9, 13, 19–21, 23, 32, 34, 36], who already provide comprehensive approaches to designing ACs in their communication and interaction abilities. Hence, our study builds on and suggests a companion design concept based on findings in the literature.

(3) Exploring AC types: In addition, we also want to understand how ACs are distinguished in the scientific literature so far. We do so by exploring AC scenarios and use cases that scientific literature discusses. The majority of existing typologies allocates their groups according to application fields (e.g., [11, 32]), the role of an agent (e.g.,[9, 13, 19]), or along identified user needs (e.g., [17, 22, 31, 35]). On their basis, we structured our findings and additionally included indicators of AC types from papers that do not explicitly provide a typology.

In summary, our research questions are: What classifies an AC (RQ1)? Which characteristics compile an AC's social design (RQ2)? And how to distinguish AC types (RQ3)? The paper is structured as follows: We first describe the research procedure in Sect. 2. Sections 3, 4 and 5 present our synthesis for answering RQ1, RQ2 and RQ3. In Sects. 6 and 7, we discuss our findings in a broader context and reflect on the limitations of the study, and we conclude in Sect. 8.

2 Systematic Literature Review

In this section, we present the methodology of the conducted literature review. As depicted in Fig. 1, the review was structured and realized in four dedicated steps: (1) sys-

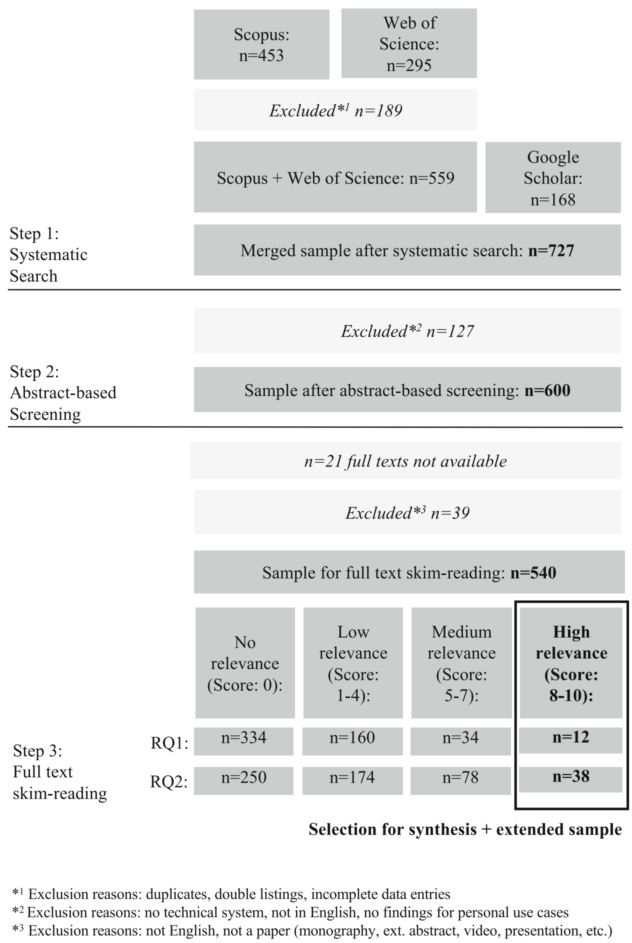

Fig. 1 Flowchart diagram summarizing the searching, exclusion, and inclusion process of the conducted SLR

tematic search, (2) abstract-based screening, (3) full text skim-reading and coding, (4) including an extended sample.

2.1 Systematic Search

In the first step, papers explicitly addressing ACs had to be identified. For this purpose, three databases were used: Scopus, Web of Science and Google Scholar. Across all three databases, the same search string was applied to identify papers. Either the title, abstract, or keywords had to contain the following search terms: *artificial-companion*, *companion-system*, *companion-characteristics*, *companion-technology*, *robot-companion*, *artificial-friend*, *artificial partner*, *robot-pal*, *robot-mate*, or *robot-team-mate*. These search terms were derived from a non-systematical review initially conducted to set the scope of the topic. Here, literature was identified according to the snowball principle and the papers were analyzed for central AC-related concepts. Furthermore, the publication year was limited from 2000 to 2021 to focus on research from this century.

The search in Scopus was conducted on April 22, 2021 and on April 23, 2021, via Web of Science. From both databases a list of papers was exported the same day. Based on the search terms mentioned above, the search via Scopus resulted in n = 453 papers, whereas n = 295 papers were identified via Web of Science—resulting in n = 748 papers. A duplicate check excluded n = 180 papers. In addition, n = 9 papers were removed due to incorrect data entries—remaining in n = 559 papers. Since search findings cannot be exported in Google Scholar, the extraction of search results took place on 9 days between May 03, 2021 and May 30, 2021. This process was documented as the number of results varied on different searching days (ranging from 9.400 to 9.550 results). Also, we sorted the findings by relevance and exclude patents and citations to narrow down the results to a feasible number and relevant work. Only papers within the first 50 Google pages were checked whether they were already included in the Scopus and Web of Science lists. As a result, n = 168 papers could be added through the Google Scholar search yielding n = 727 papers in total after step 1.

2.2 Abstract-Based Screening

Within the abstract-based screening (ABS), n = 727 abstracts were read to exclude papers out of the topic's scope. To do so, we assigned an ID to each paper in step 2. Afterward, only the abstract text and the ID were displayed for the ABS to avoid priming effects through paper titles or names of known researchers. While reading the abstracts, a so-called ABS-score per paper was created applying AC criteria that were pre-defined, pretested (n = 20 papers), and then refined. This procedure resulted in five initial AC criteria, to set the scope for the review, which are: (1) a technical system is discussed, (2) the focus is not on industry-centric solutions, (3) theoretical considerations of ACs as a concept are reflected, (4) properties or functionalities are addressed, and (5) possible application areas and AC types are mentioned.

Criterion 1 became necessary as the search resulted in papers referring to companions in different contexts than human–machine interaction e.g., astrophysics. Through applying criterion 1, only papers referring to an AC as a technological artefact remained in the dataset after the ABS. Regarding criterion 2, we must stress that ACs might be relevant for industrial applications as well—see, for example, research on cobots as provided, e.g., by [37–39]. For this study, however, we chose to focus on personal settings (including daily use cases at home and at work) since we assume the social design is of greater importance in personal contexts allowing a more detailed description. Nevertheless, future work should also study the specifics of an AC's design in industrial use cases. We assessed each abstract according to the mentioned criteria and applied the following scheme: the criterion probably is discussed in the paper = 1 point; not sure if the criterion is discussed in the paper based on the abstract = 0.5 points; based on the abstract it becomes clear that the criterion is not discussed in the paper = 0 points. We added the points per criterion together and formed the ABS-score (maximum of 5 points). We used this quantifier firstly to determine the paper's suitability for answering our research questions and secondly to determine a reading order for step 3 (the full text skim-reading). The ABS reduced the sample by n = 127 papers to n = 600 papers. Papers were excluded if they received an ABS-score of 0 or when the paper was not in English.

2.3 Full Text Skim-Reading

Within step 3, the full text skim-reading (FTS) n = 21 papers had to be excluded since their full text was not available (3.5% of the ABS-sample, n = 600). The most common reason for inaccessibility was a paywall (n = 12 papers). Besides, n = 39 papers were excluded due to further exclusion criteria (search finding was not a paper, but a monography, presentation, only an extended abstract, etc., or the paper was not in English). In summary, this results in n = 540 papers to be fully read in step 3—starting with the papers with the highest ABS-score and reading from newest to oldest within one scoring point. Figure 2 shows how many papers per year were included from our systematic sample.

In this step, new assessment scores were defined to determine the papers most relevant for the SLR synthesis—the so-called FTS-scores. Precisely, one FTS-score per research question was calculated in step 3. To build the FTS-score for RQ1, definitional statements were identified and coded into a dataset. Similarly, all discrete statements about a communication or interaction characteristic were processed accordingly for the RQ2 FTS-score. The scale of the FTS-scores ranges from 0 to 10 points. Thereby, 0 points mean an FTS score of 0, indicating that a paper contains no statements referring to the subject of the research question. An FTS-score of 10 means a paper contains ten or more unique statements concerning the corresponding research question. From the FTS-scores we deduced two relevance rankings for answering RQ1 and RQ2 with indicating a score 0: no relevance; score 1–4: low relevance; score 5–7: medium relevance; score 8–10: high relevance. This procedure was applied to the entire systematic sample (n = 540 papers) to calculate two FTS-scores per RQ and per paper. Afterward, to restrict the SLR's scope, only papers with an FTS-score between 8 and 10 were selected for an in-depth analysis, resulting in n = 12 papers for RQ1 and n = 38 papers for RQ2.

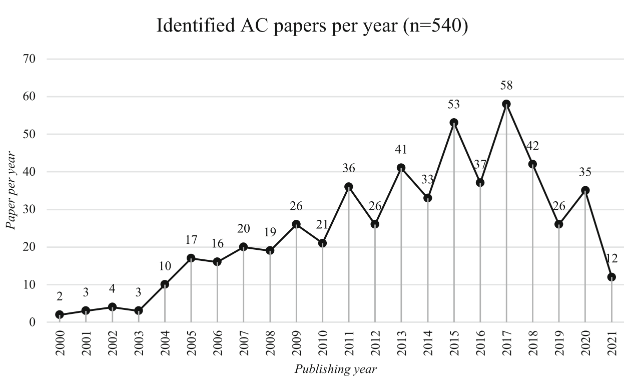

Fig. 2 Number of papers per year which were fully read in step 3 of the SLR

Unlike RQ1 and RQ2, we answered RQ3 not through a systematic paper selection. This is because papers usually discuss just one AC project, type or use case. Thus, the FTS score, which we apply to quantify the fit of a paper for answering a research question, is of no help here. Instead, for answering RQ3, we re-analyzed the high-relevance papers from our systematic sample.

2.4 Extended Sample

Additionally, we included further publications in this review supplementary to the systematic search. For this extended sample, we considered recent literature primarily from social technology-centric journals and conference proceedings including an additional snowball search. The extended sample was not systematically aggregated but resulted from a subjective selection process. We used the initial AC understanding gathered from first analyzing the systematic sample to then recursively add publications that deal with AC characteristics without using the term AC or that did not appear in the systematic search. In this paper, we summarize the findings from the systematic and the extended sample, in one place. However, to allow transparency and differentiation from the subjective selection, the systematically generated study materials (review protocol and datasets) are available in the Open Science Framework.[7]

3 What Classifies an AC?

Before answering the research questions, it is reasonable to point out some general aspects of the research field: First, its inter- or cross-disciplinary nature [8, 9, 11–14], that influence differences in existing definitions or emphasis on diverse components in the design. Therefore, our analysis searched for commonalities in these definitions and derived key characteristics to suggest an inclusive AC definition that addresses a diverse research field. Second, scientific literature often associates the companion concept with long-term endeavours to create artificial beings that

[7] http://bit.ly/3wFyyxl.

serve and accompany humans [8–10, 15, 17]. Here, historical, and religious references are easily introduced [40]. Nevertheless, we limit this analysis to technological artifacts and apply our findings to social agents that interact with humans, such as robots, avatars, or voice assistants. So, while the effort to develop an AC is by no means new, still, we see increasing research interest on this topic over the past 20 years. Searching for a starting point of AC research, we found a couple of articles [3, 14, 21, 41] referring to a 2005 publication by Wilks [42]. Notwithstanding, we must add that there is substantial research directly or indirectly addressing an AC's characteristics before 2005 (e.g., [16, 22, 43–45]). Also, some papers link AC research to a paradigmatic understanding in human–machine interaction (HMI) and especially human–robot interaction (HRI) [11, 13, 20]. Within the companion paradigm, the attribution as an AC is dependent on the user perception, which requires to conceptualize design features from the perspective and attitude they elicit in the user [16, 44–47]. For the definition of ACs, this means that an agent ascribed as an AC is not based on manifest properties, but rather is caused through the interaction with the user. Therefore, in our first research question, we separate the key AC characteristics from potential design properties. While searching for key characteristics that are fundamentally attributed to agents described as a companion, we notice some recurring characteristics in the literature. Biundo and Wendemuth [20, p. 2], for instance, name "competence, individuality, adaptability, availability, cooperativeness, and trustworthiness" as central AC characteristics. Similarly, Kritzler et al. [19] consider shared knowledge base, adaptability, and embodiment as critical for ACs. Böhle and Bopp [9] go in this direction as well and define, based on an expert survey, sensing, learning, adaptation, multimodal interfaces, and autonomy as essential AC qualities. Accordingly, we identified some characteristics that provide relevant prerequisites for ACs (e.g., trustworthiness) from the literature review but which are insufficient to distinguish ACs from other social technologies. So, by further comparing existing AC approaches, we could identify two characteristics addressing the principal idea researchers, and developers pursue when developing an AC: **adaptivity** and **engagement**. We chose to focus on these two properties as they first, continuously appear in the literature, and second, allow us to unify related concepts in given AC definitions. Also, focusing on these two characteristics broadens our AC understanding, especially since agents can exhibit adaptive and engaging behavior in various design combinations and application areas, as we will show in the following.

Adaptivity, as the first central AC characteristic, enables the agent to react to the user and the social environment they are embedded in. Adaptivity is already shown very basally in the agent being responsive to the user. This can be expressed by looking at the user or reacting to the user's actions. Consequently, literature links adaptivity to large sensing and recognition capabilities, such as face recognition to register and distinguish users (e.g., [4, 20, 43, 48, 49]). More sophisticated agents show adaptive behavior by involving the user's preferences, abilities or needs (e.g., [1, 19, 20, 23, 50]). Hence and in addition to recognition, adaptivity requires memory capacity to build up knowledge bases and user profiles (e.g., [7, 12, 19, 30, 32, 32, 51]). Furthermore, high levels of adaptivity imply an agent that reacts adequately to the (situative) context of the user, e.g., if the user is stressed, the AC choses a reduced communication style. Such advanced adaptive capabilities have been addressed in the literature along with emotion recognition and management systems, which intends to create empathic agent behavior (e.g., [32, 51, 52]). Adaptivity also means to consider cultural conventions just as subjective user expectations to achieve higher acceptability (e.g., [23, 53]). In general, with adaptivity, AC designers aim for personalized interactions by tailoring the functionality to individual users in light of increasingly complex technology (e.g., [19, 23, 41, 49]).

Adaptivity also sets the course for our second key AC characteristic, **engagement**, as only adaptive systems can be engaging systems. We assess engagement crucial since recent studies report that long-term human–machine interaction will fail without engagement of the user [23, 54]. Engagement basically means that the agent takes action, approaches the user on an emotional level and initiates interactions. Accordingly, an agent might demonstrate engagement in various ways that intend to keep the user in an interaction or resume at a later time. As with adaptivity, engagement already shows in simple actions, such as greeting the user or responding positively to their presence [23]. In this context, nonverbal communication, particularly the ability to display emotions, is frequently taken up in the literature (e.g., [22, 44, 47, 55–59]). Moreover, we see a link between engagement and proactivity as well as persuasiveness, e.g., expressed in an agent making suggestions, sharing recommendations, or motivating the user to do something. Advanced forms of engagement include personality-rich agents that are, e.g., funny, chatty and tie in with previous interaction to evolve an interaction into a relationship [1, 41, 52, 60]. Hence, evoking positive emotions in the user is fundamental to encourage engagement and create pleasant interactions.

Both adaptive and engaging behavior facilitates reciprocity and self-disclosure, which in turn affects the user's emotional state and creates meaningful interaction [45, 47, 48, 52, 60–65]. Accordingly, with the two key AC characteristics, we combine the opportunity to reduce the object character of an agent - which could lead users to assess it rather as a social actor than a tool that one easily can replace [13, 46]. Our review also revealed that developing ACs strives to form emotional bonds between a user and an agent, intending resilient human–machine teams and

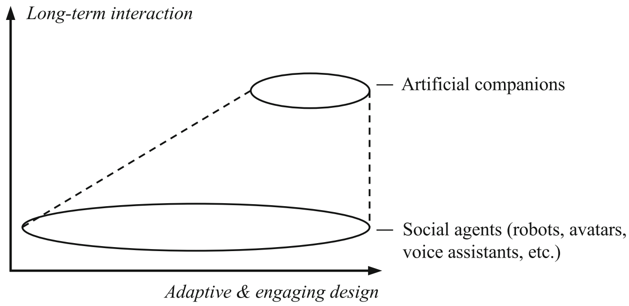

Fig. 3 Figure illustrates the assumption that some agents become ACs through the course of long-term interaction and based on their social design

establishing companionship [8, 9, 11, 20, 22, 41, 60–63]. Hence, the focus on adaptivity and engagement makes ACs an interesting design concept for a range of social technology. Although, at the same time, we would like to differentiate that not every social agent is an AC. Instead, we assume that an AC results over time from an agent showing adaptive and engaging behavior, or rather, the user perceiving it as such [5, 8, 11, 13, 21, 30, 41]—which we schematically illustrated in Fig. 3. In other words, we can say that an AC only exists in the perception of the user. Therefore, an AC cannot be universally "produced", but we argue that designing for adaptive and engaging behavior fosters the perception of an agent as an AC.

To give a summary and answer RQ1 in short, *we suggest defining artificial companions as social agents characterized by adaptive and engaging social design pursuing emotional bonds with their users*. Prominent AC examples indicate a latitude in how adaptive and engaging design is realized in practice. For instance, Paro [64, 66], an animal-like robot in the field of aged care, expresses its adaptivity and engagement exclusively via nonverbal communication and simple sounds. Different from Moxie, a human-like learning and therapy robot, or ElliQ, a thing-like personal assistant, who are additionally equipped with verbal capabilities and enable multimodal interaction. Although the three examples differ in their social design, we can classify them to different degrees as adaptive and engaging. This brings us to the second part of our analysis: which features in the communication and interaction design convey adaptive and engaging behavior to the user.

4 Which Properties Compile an AC's Social Design?

In this section, we summarize how researchers and designers approach the key AC characteristics, adaptive and engaging behavior, in the agent's design. To do so, we analyzed variations of design features and sort them into categories, which we regard as essential components in an AC's design. As design features we understand properties that shape the communication and interaction between agent and user - this concerns, for example, abilities, assets, or components in the architecture. We do not discuss the technical implementation. Instead, we focus on how the features appear towards the user and what effect they have on the interaction. As we suppose the communication and interaction qualities crucial for receiving the companion label from a user, this section starts with central communication modalities. After that we look at the interaction properties structured in features pursuing adaptive and engaging behavior. To these we add findings on the agent's personality, embodiment and outer design (appearance), which our analysis revealed to be likewise relevant for the social design

4.1 Communication Qualities

Our assumption that communication capability is central for an AC to elicit social responses from the user finds support in a body of work (e.g., [20, 43, 44, 54, 60, 67–71]). Biundo and Wendemuth [20], p. 11], for instance, argue that "dialogue nature" is the main asset of an AC. Also, Dautenhahn et al. [68, p. 4] support the role of human-like communication ability by providing empirical evidence of participants' preferences. In this context, Toptsis et al. [67] point out that naturalness in human–machine interaction is enabled by "spoken language as the main modality and additional natural modalities like, e.g., gestures and mimics" [67, p. 1]. Accordingly, Wrede et al. [43, p. 6] emphasize "that a robot companion has to show acceptable communication skills in order to be acceptable both at a social and a functional level." Research shows two main resources to achieve natural and intuitive communication in ACs: verbal and nonverbal communication. Many studies focus on ACs' ability to produce comprehensible spoken language and understand user's speech (e.g., [2, 7, 19, 22, 30, 48, 51, 72–75]). Other studies focus on nonverbal assets, which must be equally readable and thus understandable for the user (e.g., [47, 69]). Hence, the first essential property we can derive from the analysis is that both verbal and nonverbal communication, including different forms of semantic free utterances [36, 58], are important for enabling natural and intuitive communication in ACs.

Likewise, verbal and nonverbal communication are important in conveying emotions and intentions, making the agent appear credible and desirable for engagement (e.g., [22, 44, 47, 55–59]). Therefore, the alignment of verbal and nonverbal communication is crucial in making interactions livelier and authentic, especially when speech is the main modality (e.g., [6, 22, 41, 76, 77]). Nonverbal communication can be achieved through facial expressions (e.g., [4–6, 21, 44, 75, 78, 79]), gestures (e.g., [1, 4, 5, 21, 49, 69, 79]), emojis, and other visual elements (e.g., [51, 80]). In particular, animated displays are considered the easiest way to produce facial expressions due to their expressiveness and flexibility without requiring complex hardware [3, 4, 6, 7, 51]. Anthropomorphic features such as facial expressions and body movements are ideal for nonverbal expressiveness. At the same time, non-human features such as colours, lights, sounds, purring, heartbeats, or breathing movements may also accomplish expressive agent communication as we found in [5, 64, 69, 81]. Furthermore, to support social connectedness and signal attention an AC should look at the person speaking to it (e.g., [13, 48, 70, 78, 82]). Regarding how permanent this eye contact should be, we found the strategy to avoid steady gaze and occasionally look around or daydream in passive interactions [44, 77, 82]. The intention behind this is to let the agent appear more natural and less uncanny. However, at the same time such behavior user could judge as shy, anxious or introvert [83], which is why looking at the user, looking away and looking around must be harmonized. In general, eye contact is usually realized through gaze and sound localization abilities [6, 48, 49, 73]. In case of agents with less verbal skills, we assess gaze or simple sound localization particular to signal attention and responsiveness which support user engagement in spite of limited communication abilities. Paro, Vektor or Jibo are a good example here, as they primarily create closeness through pleasant sounds, gentle head and body movements, eye contact and blinking.

Another point that we find strikingly often in the literature is the flexibilization of the communication situation through multimodality [12, 76], e.g., by alternating the preferred modalities or communication styles when the situation changes [7, 51, 69, 84]. For instance, on some occasion communication using speech is more convenient (e.g., selection of a time and date) whereas in other contexts using gestures is more natural to users (e.g., swiping through calendar pages). Accordingly, Siegert et al. [84] determine multimodal human–machine communication to be intuitive human–machine communication.

In summary, properties we assess essential for an AC based on this section are:

- natural and intuitive communication ability
- combinations of verbal and nonverbal communication modalities
- alignment of speech with nonverbal elements (given the AC uses spoken language)
- simulation of eye contact for attention and social connectedness
- flexibility in communication through the use of multiple modalities

4.2 Interaction Qualities

The complexity of AC designs become further evident reflecting on the variations in the interaction abilities. In this section, our findings are structured into five categories: user and context adaptivity, engagement, personality, embodiement and appearance.

4.2.1 Adaptivity to Users

Adaptivity as a key characteristic of ACs (see Sect. 3) is also considered in terms of design features by several articles in our review. Adaptivity to a user implies that an AC has the ability to recognize and distinguish users - starting with knowing their names [32, 73, 75, 76, 79, 85]. More advanced ACs can interpret and respond appropriately to a user's emotional state, e.g., through analyzing facial expressions (e.g., [7, 73]), gestures (e.g., [73, 84]), and touches (e.g., [64, 86]). Empathy is also considered an asset in highly adaptive behavior, that allows the AC to predict and react to the user's emotional state [12, 14, 19, 20, 32, 64, 74, 87, 88].

Another aspect that raised our attention conveys the idea that the interaction between the agent and user becomes more personalized through demonstrating the agent's learning process (e.g., [13, 14, 16, 19, 61, 89]). According to the literature learning processes can be either user-initiated or co-dependently when both, the user and agent learn alongside [13, 14, 43]. For example, learning a personal greeting ritual like a handshake, using the same dialect or slang, or having the same sense of humor [23]. Additionally, some authors suggest an AC should learn relevant information about the user from dialogues and other interactions [2, 19]. This implies self-initiated learning processes - without the user actively telling the agent what they like or find important.

Likewise, adaptivity associated with advanced recognition abilities is crucial for multi-user scenarios as these are more natural in practice, but also require gathering and processing large amounts of user and context data from various sources [1, 51]. This makes privacy a major challenge in personalized human–machine interaction, as concerns can limit willingness to use an AC [50, 51, 60, 90, 91].

The main characteristics of ACs as described in this section are:

- recognition and distinction of users (e.g., knowing their names)
- interpreting and responding appropriately to a user's emotional state (e.g., empathy)

- demonstrating self-initiated or collaborative learning processes to form personalized interaction
- gathering and processing large amounts of user data while assuring privacy

4.2.2 Adaptivity to Context

Context adaptivity enables an agent to understand and respond appropriately to different situations and environments (e.g., [19, 20, 49, 79, 88]). Therefore, we suggest context adaptivity also crucial for user adaptivity since users are steadily embedded in situative contexts. As with user adaptivity, the basis for context adaptivity lies in recognition and sensing abilities. Context adaptivity is based on the agent's recognition and sensing abilities, including its ability to identify spaces in the environment, as well as associate objects with the function they fulfil in that space. Additionally, we can summarize from the literature review an AC must continuously analyze the environment (e.g., [4, 19, 20, 88]) and dynamically adjust to changes in its environment (e.g., [12, 19, 22, 30, 84]). A good example for the implementation of companion characteristics in public spaces is the ticket vending machine in [84]. The contextual adaptivity shows in the agent evaluating how fast a person approaches the vending machine and types in their data. If it determines that the person is in a hectic situation, it will skip unnecessary information and help the user to get their ticket quickly.

Furthermore, adaptivity requires taking cultures specifics into account - such as social norms, rules, values, habits, symbolic meaning of colors, gestures, or customs in human–human communication like social distance or eye contact [6, 23, 52, 53, 77]. This allows the agent to understand the situation in which an interaction is taking place and behave in the user's best interest. For example, take a dinner party where a plate is broken, which the home robot sweeps up - generally, we would consider this behavior appropriate. However, if we change the situation into a wedding, several cultures see shards as a sign of good luck and could get mad with the robot cleaning these instantly. Adding the cultural variable, being a highly adaptive agent would imply to first understand different situations and then included knowledge on social norms and customs when tailoring the next action. Likewise, context and cultural awareness are vital to understand the background of emotions and display appropriate communicative behavior towards the user [19, 20, 23]. Pesty and Duhaut [34, p. 240] state in this regard: "Social norms on communication: contrary to computer interface an artificial companion must respect some social norms to engage an activity. For instance, must find an acceptable distance from the user (interpersonal distances), look to the user while speaking, open the communication with polite gesture, respect of speaking slot." So, adaptive design respects not only user specifics but also considers their situative background.

In summary we can derive the following set of potential characteristics from this section:

- an adaptive companion continuously analyzes the environment and dynamically adjusts to changes
- context adaptivity requires considering cultural specifics such as social norms, values, and habits
- context awareness enables appropriate behavior towards the user' emotions
- an adaptive design respects both user and cultural specifics

4.2.3 Engagement

Engagement as the second key AC characteristic includes abilities like displaying intentions and emotions, being proactive and initiating interactions with the user [2, 3, 7, 48, 49, 51, 58, 64, 79, 87]. Certainly, our results suggest a strong association between engagement and the emotional status of the user. Emotional engagement implies perceiving the user's mood, listening or helping to cope negative emotions [5, 41, 47, 48, 52, 72]. Practical AC examples applying these features are Emobie [5] or Moxie. Moreover, emotional engagement includes showing interest and affection towards the user as well as reaching for enjoyable interactions [12, 20, 23, 34, 44, 49, 51, 52, 60, 70, 72]. This is, for example, an agent that welcomes the user, stimulates conversation, entertains them, or simply reacts positively to endearment shown by the user. Hence, with the requirement of engaging and especially emotional engaging ACs, users gain an agent acting in their interest or at least, trying to be a source of stress reduction [12, 20, 85, 92].

The concept of reciprocal involvement is also related to engagement and involves the agent participating in the user's activities, like offering suggestions, actioning alternatives, sharing ideas, complimenting, or motivating the user [12, 20, 41, 51, 52, 64, 78]. On the other hand, reciprocal involvement could mean an agent actively demanding the user's attention or participation and thereby involving the user into its own activities. This can show, for example, by the agent asking for help or explaining its behavior transparently [1, 20].

Some studies also suggest that an AC should monitor the user's engagement level and adjust its behavior if necessary (e.g., [34]). This is especially useful in educational and therapeutic contexts, where the agent serves as a coach or learning partner (e.g., [51]; also see Sect. 5.4). In these cases, the agent should respond if the user becomes less focused or bored. However, in other scenarios, such as a relaxed Sunday afternoon, this feature may not be necessary, highlighting the importance of context adaptivity.

The use of engaging technology also raises ethical concerns, as it may result in social isolation if users opt for interaction with machines over human interaction. However, some ACs counteract this risk serving as facilitators and enablers for human–human interaction. For example, by providing support for video calls, web browsing, suggesting meeting friends, or simply being the center of attention about which the attendees chat [51, 52, 89]. Consequently, research shows that also mediating functions favoring interpersonal communication can support the adoption of an agent [91].

For the design of engaging behavior in ACs, we consider the following properties to be essential:

- displaying emotions
- proactively initiating interactions with the user
- responding to the user's mood
- reaching for pleasant interactions
- involving the user in an activity
- also enabling human–human interaction

4.2.4 Personality

Benyon and Mival emphasize the significance of personality design in their work, stating that "[a]s soon as interaction moves from the utilitarian to the complexity of a relationship, people will want to interact with personalities that they like" [41, p. 21]. Similarly, Vaswani et al. [22] stress the importance of testing personality attributes, as neglecting to do so may result in the rejection of the AC system, regardless of its technical abilities. Our review found that designers of ACs often utilize established (human) psychological models to define the agent's personality [77]. By examining personality descriptions, we observe recurring attributes, such as humor and talkativeness (e.g., [51, 71]), which shown to enhance user bonding (e.g., [60]). Other research highlights friendliness, cooperativeness, and trustworthiness (e.g., [5, 13, 20, 85]), or notes that ACs should not exhibit patronizing, hostile, dominant, or cynical behavior (e.g., [1, 13, 21, 85, 87]). Dautenhahn addresses personality development by introducing the term robotiquette as "a set of rules or heuristics guiding the robot's behaviour" [13, p. 689].

Other important personality attributes our review revealed include empathy [41, 72, 79], responsiveness, proactivity or enthusiasm [5, 19, 20, 70], predictability, and controllability [13, 68]. A few authors also consider strategies against habituation effects and suggest an AC to act surprisingly, for example, by falling out of known behavioral patterns [1, 13, 13, 21].

With regard to options in the personality design, we would like to summarize the following findings:

- recurring attributes: humor, talkativeness, friendliness, cooperativeness, trustworthiness, empathy, responsiveness, proactivity, predictability, and controllability
- attributes to avoid: patronizing, hostile, dominant, or cynical behavior
- include surprising and unexpected behavior

4.2.5 Embodiment and Appearance

In our analysis, it is evident that an AC can have different forms of embodiment. The majority of the ACs mentioned in the review are social robots, such as Nao [49], Arash [4], Paro [93], Emobie [5], iCat [79], or EmotiRob [75]. Other embodiment forms synthesized are screen-based avatars in 2D, 3D, or as augmented reality [19, 41, 85, 87]. Ambient intelligence is barely discussed but can be implicitly synthesized when we look at the papers discussing the idea of multi-device migration for an AC [5, 12, 22, 41, 76, 85]. In principle, an AC could also have no visual presence - meaning that it simply appears auditory, such as today's voice assistants. In this case, however, nonverbal communication abilities would be significantly limited, which is essential to allow intuitive and natural human–machine communication [44, 69]. Thus, a mere audio appearance is barely discussed in the analyzed papers. Instead, audio-visual combination is the most common combination and some authors explicitly emphasize physical presence and embodiment to elicit social responses from the user [4, 47, 57, 94]. In this regard, Giorgi et al. [49, p. 258] underline that embodiment helps users to "create social and emotional attachment".

When an AC is realized as a robot, the identified variants of locomotion are static movement, wheeled locomotion, and walking [4, 49]. According to Meghdari et al. [4], most of the robots do not move in the environment (50%), more than one third (35%) can move by wheels, and only a small portion can walk (15%). If an AC can move in the environment, it should approach the user preferably from the side and not frontally. Also, it is required to keep an appropriate speed respect social norms in interpersonal distance to allow the user getting comfortable with the situation [23, 34, 78].

After this section has focused on the embodiment, we will now differentiate common appearances our review revealed. In general, literature discusses human-like, animal-like, and thing-like or abstract (e.g., [4, 41, 52, 60, 64] shapes of ACs. Lehmann et al. [6] point out that an AC needs to show anthropomorphic or iconic features, that resemble a human or an animal. They explain: "It seems that people are unable to interpret facial features beyond a certain level of abstract and that this inability creates an uncertainty when being confronted with a robot, that makes an interaction uncomfortable and unpredictable" [6, p. 389]. A recent study by Paetzel et al. [95] confirms that anthropomorphic appearance positively impacts the interaction with an agent. However, at the same time, a high degree of human-likeness (in terms of realism) can also lead to rejection, as e.g., Thaler and colleagues [96] show. Although in practical examples we can see facial features fairly reduced while still allowing a high level of expressiveness as the one-eyed Jibo shows. This leads to another strategy we found in AC research that prefers a simple design without too many details [6, 23, 68]. Consequently, since an AC already communicates and interacts very human-likely, we still suggest anthropomorphic cues in appearance but advise against a high degree of human-likeness in the outer appearance to avoid the Uncanny Valley (describing the effect of decreasing acceptance towards a nonhuman entity the more human-like it appears; see, for instance, [97, 98]). In addition, Benyon and Mival [41] suggest that the AC's appearance could evolve over time - meaning that the AC becomes not only more personalized but also changes its look in a long-term relationship, e.g., gets older. Furthermore, research has shown that people associate the agent's appearance with potential competencies and roles [32, 99]. Consequently, certain appearance types could increase the barriers for an agent in some application areas, for instance, an animal-like robot that is not taken serious in an education or business context. Reflecting the complexity appearance expectations bring to design process, we see consistent research efforts towards design implications for different user groups, application fields and societies (e.g., [23, 47, 51, 53, 77]). Moreover, as outlined above several papers in our analysis emphasize that AC design should match not only user preferences but also cultural conventions [6, 23, 52, 53, 77, 100]. However, this ambition does not align with the appearance of today's commercial ACs. Many of them are companion robots with a similar design, such as white or light colors, round body shapes, big eyes, and large heads [101, 102]. These cues aim for adorable and non-threatening robots eliciting social responses from users comparable to those towards animals or human children [44]. Looking at the practical realization of ACs, cuteness seems to be a reliable strategy. Although we need to reflect that while cuteness promotes positive affects and responses, it also limits the user's expectations towards the agent [32, 59].

From this we can summarize the following properties on an AC's appearance:

- common embodiment forms include robots, screen-based avatars and voice assistants
- anthropomorphic or iconic features are recommended but a high degree of human-likeness is advised against
- the appearance should match user preferences and cultural conventions
- reflect that appearance impacts user expectation towards behavior and competencies of the agent

5 How to Distinguish ACs?

During our literature review, we encountered a multitude of scenarios discussing ACs in various contexts. As ACs are meant to accompany us through our daily lives, we suggest it not reasonable to sort an AC into strict types - or in other words, we would allow an AC to fulfill more than one type (e.g., [50]). Accordingly, the following section describe potential types that an AC can represent based on (a) the social role they perform, (b) their primary associated competencies, (c) the users they serve, and (d) the application areas where they are likely to be most prevalent. Table 1 provides a summary of the suggested AC types.

5.1 Personal Assistants and Servants

One role we identified recurringly in the review is that of a personal assistant, butler or servant (e.g., [1, 7, 9, 12, 19, 22, 35, 67, 68, 73, 79, 85]. This type is often linked to two competencies we illustrate in the following: assisting tasks and information management.

Throughout the analysis, we noticed a dominance of **assistive tasks** in the literature, however without directly referencing an assistant or servant role (e.g., [1, 7–9, 11–13, 17, 19, 20, 22, 35, 49, 68, 73, 78, 85]). In general, it is essential to emphasize that ACs not intend to replace human assistance but to enable users and extend their capabilities (e.g., [9, 76, 88]). Accordingly, users benefit in terms of receiving cognitive and physical support, which allows them to be more independent and have time for other activities. In practice, assistive tasks mean that the AC helps the user with their schedule, sets reminders, assists in daily activities, or carries out the user's commands (examples given in, e.g., [17, 31, 41, 73, 78]).

Managing information is the second competency we identified in several papers (e.g., [12, 17, 19, 20, 22, 30, 41, 81, 84]) that suggests a close link to the assistant role. Examples for the practical execution of information management tasks are the agent collecting, sorting, filtering, or sharing information appropriate and relevant to the users as described in [103] or [30]. We found information managing competencies add value to the interaction by reducing stress through tailored information load [19].

Although literature often discusses ACs for vulnerable groups, we consider assistant and servant ACs evenly relevant to general users (without special needs). Specifically, this includes users in application areas like personal assistance in everyday activities (e.g., [9, 12, 20, 22, 35, 41, 73, 79, 85]), driving assistance (e.g., [11, 104]), smart home environments. (e.g., [1, 11, 13, 35, 43, 67, 68]), or customer service in public spaces (e.g., [6, 41, 70, 84]). At the same time, assisting ACs might not be only interesting in private but also in professional contexts [8, 12, 19, 32]. The coworker

Table 1 Gives an overview on potential AC types with their associated role, competencies, user groups and application areas

Role	Primary competencies	User groups	Application areas	Examples
Personal assistants and servants	*Assisting in daily activities* • e.g., schedule appointments, set reminders, shopping assistance, carrying out general user's commands • Benefits for the user: receiving cognitive and physical support *Information management:* • e.g., collect, sort, filter and share information relevant for the user • Benefits for the user: tailored information load and enhancing the user's knowledge as well as informedness	General population	Daily life at home [9, 12, 20, 22, 35, 41, 73, 79, 85] and at work [8, 12, 19]; driving assistance [11, 104]; smart homes [1, 11, 13, 35, 43, 67, 68]; customer service [6, 41, 70, 84]	ElliQ[a]; Zenbo Junior[b]
Friends, partners and companions	*Emotional care* • e.g., monitor the user's state and initiate social interactions, such as chatting with the user, entertaining them, or playing games (companionship-as-a-service) • Benefits for the user: improve well-being and reduce anxiety, depression, loneliness *Social inclusion* • e.g., communication intermediary - help with daily online communication, remind meeting friends/family, or suggest events • Benefits for the user: reduce social isolation, help with building and maintaining interpersonal relationships	General population; people living alone or in a secluded place; older people; impaired users; patients; pupils and students	Aged care and assisted living [1, 9, 17, 49]; hospitals, therapy, and rehabilitation facilities [2, 4, 5, 30, 32, 35, 75]; schools and other educational contexts [4, 8, 9, 51, 88]	ElliQ;Gatebox[c]; Replika[d]; Vektor[e]; Jibo

Table 1 continued

Role	Primary competencies	User groups	Application areas	Examples
	Digital inclusion • e.g., technology assistance - operating a device, navigating on the internet • Benefits for the user: enhanced independence to manage their own daily life			
Nannies, caregivers and guardians	*Monitoring and supervising* • e.g., look after the user or health monitoring like tracking vital data and calling caregivers or an ambulance in an emergency • Benefits for the user: increased sense of safety for both, primary and secondary users *Medical care* • e.g., reminding about medication, correct dosing, refilling the pill box, or medical appointments • Benefits for the user: independency and empowerment to take care of their own *Emotional care* • e.g., monitor the user's state and initiate social interactions to distract from negative emotions • Benefits for the user: social interaction in addition to medical treatment *Motivating and activating* • e.g., initiate exercises and suggest activities • Benefits for the user: receive motivation and mental support	Older and impaired people; (young) patients; pupils and students	Aged care and assisted living [1, 17, 31, 49, 54, 60, 88, 89, 93]; hospitals, therapy, and rehabilitation facilities [2, 9, 11, 35, 88]; children with medical conditions [4, 8, 9, 51, 88]	Arash [4]; Emobie [5]; ElliQ

Table 1 continued

Role	Primary competencies	User groups	Application areas	Examples
Teachers and choaches	*Educating* • e.g., guiding, teaching, or explaining an activity or new skill • Benefits for the user: individualized training sessions and personal support to reach goals	General population; older and impaired people; young patients; pupils and students	Schools and other educational contexts [8, 9, 32, 51, 88]; health and fitness [9, 11, 35, 107, 109];	iCat [79]; Moxie[f]
Children and pets	*Demanding care and attention* • e.g., the user looks after the agents, strokes, caresses, and makes sure the agent is well • Benefits for the user: receive attention, affection and acknowledgement for their actions from another entity and; for pet-like ACs: a soft surface can calm the user and reduce stress	General population; older and impaired people; young patients	Aged care, therapy and rehabilitation [66, 93]	Paro [66, 93]; Qooboo[g]; Emo[h]

[a] https://elliq.com
[b] https://zenbo.asus.com
[c] https://gatebox.ai/en
[d] https://replika.com
[e] https://www.digitaldreamlabs.com/
[f] https://embodied.com
[g] https://qoobo.info/index-en
[h] https://living.ai/emo/

AC rarely appears in this analysis, possibly due excluding "cobots" from the search terms as it revealed industry over personal use cases. Nevertheless, we consider ACs in workplaces as equally obvious and suitable for this AC type, especially when it comes to information management tasks like decision-making support (e.g., [19]).

5.2 Friends, Partners, and Companions

The second most common role is directly referred to as the companion, friend, or robotic mate (e.g., [1, 7–9, 13, 17, 68, 72–74, 85, 88]). Although, we must state that agents performing the friend role are not equal to the companion paradigm itself. The companion paradigm is the overall design principle, focusing on adaptive and engaging behaviors delivered through intuitive communication and interaction as outlined in Sects. 3 and 4. An agent following this design principle can result in the friend role but not necessarily. Instead, we consider the user and usage context equally relevant to define the social role the agent might fit, especially since it is the user that references a piece of technology a companion kind. Accordingly, we argue that the boundaries between AC types may be blurred, e.g., when the user is initially relaxing at home but then needs to get something done, causing the agent to merge the friend with the assistant role.

Significantly for an agent appearing as friends, partners or companions, is that the communication with the system becomes an end in itself, showing in social interaction as the main function they serve [9]. Thus, we found conversing abilities, emotional care and engaging activities the dominant tasks in this role. Since the last two properties are not self-explanatory, the following summarises what our literature review revealed about them.

Emotional care means, for example, that an AC monitors the user's affective state and starts an interaction to reduce negative emotions, stress or harmful behavior (e.g., [4, 5, 48, 49, 64, 85]). Practical AC representatives for such qualities are, for example, in the Arash robot [4] or the robot in [48]. Through emotion recognition and emotion regulation, an AC shall improve the user's well-being and reduce the risk of anxiety, depression, loneliness, etc. (e.g., [29, 65, 66, 93, 105]). In addition, we found broadly discussed in the literature tasks to set up social interactions (e.g., [1, 4, 7–9, 17, 20, 22, 68, 79, 88]). We would like to summarize such competencies as companionship as a service [9], which implies an AC engaging the user socially and emotionally. Practical examples are the AC listening to the user, telling a story, playing games together, entertaining the user, or simply having a talk (as we found, e.g., in [4, 7, 41, 49, 73, 87]). Likewise, our analysis revealed the psychological benefits emotional engagement with an agent brings, such as higher self-disclosure, less negative emotions, stress reduction, as well as increased interpersonal interaction (e.g., [29, 66, 91–93, 106]). At the same time, an AC that extensively tries to engage a user emotionally might not be preferred in every situation, e.g., when the user is in public or in a hurry. This requires tying in emotional engagement with situation awareness and raises the need for user and context adaptivity.

A second task that we associate with the friend, partner and companion role relates to the inclusion of the user. This is social inclusion on the one hand and digital inclusion on the other. With **social inclusion** (e.g., [2, 4, 17, 35, 76]), ACs primarily act as "communication intermediaries" [9, p. 163]. For example, the AC helps the user with their daily communication, talking to others, using social media networks, remind meeting friends/family, or suggesting going to an event. Practical examples in this area are ElliQ or the robots in [76, 81]. We see the advantage of a socially supportive AC in reducing the risk of social isolation and that the agent supports the user in building and maintaining interpersonal relationships. **Digital inclusion** primarily shows in technology assistance, which, e.g., includes assisting the user in operating a device, navigating on a webpage, or acting as an interface to online communication (practical implementations of this competence we found in [49, 76, 81, 89]). The advantage of digital inclusion for the user lies in enhanced independence, or rather self-reliance, to manage their daily life without or being less dependent on others. Of course, the last two competencies might be relevant extensions for other roles, such as assistance- or service-oriented ACs (see Sect. 5.1). This illustrates the overlaps mentioned in the last section, which make it difficult to define disjunctive AC types.

In our analysis, we also noticed that the literature mentions agents with dominant friendship competencies (emotional caring, social and digital inclusion) often in the context of vulnerable groups and especially socially isolated people. Social isolation can have various reasons, such as, when a person lives alone or works in a secluded place, like in military, research, or space contexts (e.g., [9, 107]). The most common vulnerable groups we identified in our analysis include older people (e.g., [1, 17, 31, 35, 49, 54, 60, 66, 93]), people with physical disabilities or cognitive impairments (e.g., [2, 3, 64, 76]), as well as young users in an educational context (e.g., [51, 52, 79, 87, 92]), with chronic diseases, or disorders [4, 5, 30, 75, 108]). As stated in the last section (see Sect. 5.1), we suggest the friend type AC relevant for both vulnerable groups and the general population. Possible application areas we associate most likely with this type are aged care and assisted living (e.g., [1, 9, 17, 49]), hospitals, therapy, and rehabilitation facilities (e.g., [2, 4, 5, 30, 35, 75]), or children with medical conditions (e.g., [4, 8, 9, 51, 88]).

5.3 Nannies, Caregivers and Guardians

Within the next type, an AC performs the role of a nanny, nurse or caregiver (e.g., [8, 46, 49]), which is mainly discussed in context of older users in application areas such as aged care (e.g., [1, 17, 31, 49, 54, 60, 88, 89, 93]), hospitals, therapy and rehabilitation facilities (e.g., [2, 9, 11, 35, 88]), for children in therapy (e.g., [4, 5, 30, 75]) or after school activities. The following competencies are primarily considered with this type in the literature:

Monitoring and supervision abilities fit well as primary tasks into the nanny and caregiver AC type (e.g., [2, 9, 31, 35, 48, 73, 76, 81]). In some cases, monitoring and supervision functionalities are realized multimodally by embedding wearables like a smart t-shirt [48]), bracelet [81] or smartpen [76]. These competencies mainly constitute ensuring that the user stays in good condition and is less intervening in the user's actions as the next type, the teacher and coach (see Sect. 5.4) do. This is, for instance, looking after the user, or more specifically, health monitoring, where the AC tracks the user's vital data and alerts caregivers given poor health data (examples found in [2, 9, 81]). From the user perspective, the advantage for both primary (child, senior) and secondary users (parents, relatives) (e.g., [2, 3, 30]) lies in an increased sense of safety and information support. That practically shows, e.g., in having someone to watch over and take action in an emergency. A similar functionality applies to ACs in a guardian context, which literature treats as a separate AC type [8, 9, 19, 22, 85]. Still, since guardian ACs primarily serve their users with monitoring tasks, we suppose sorting such agents into the nanny and caregiver types as well.

Also particular for nanny, caregiver, and guardian ACs is the association with different forms of care work. This includes, on the one hand, care in the context of **medical care**, such as reminders about medication, correct dosing, or doctor's appointments (e.g., [3, 8, 9, 17, 31]). As with digital inclusion (see Sect. 5.2), the user benefits from being more independent and empowered to take care of their own like [22] or [49] argue. On the other hand, care also implies emotional care to assure mental health (e.g., [4, 5, 29, 48]). As with the friend-centred AC type (see Sect. 5.2), the caregiver AC could monitor the user's emotional state or initiate interactions to distract from negative emotions [4, 48, 64]. The user benefits from increased social interaction, like conversation or entertainment, in addition to medical treatment. The necessity of companionship services in technological healthcare solutions is in line with a previous review analysing the needs of older users. This emphasizes that medical does not come without emotional care to ensure overall good health and quality of life [31]. Consequently, a caregiver AC is likely to have friend competencies as well. A consistent extension to emotional care provides **motivating and activating** tasks (e.g., [3, 41, 85, 88, 107]). Here, the agent, for instance, initiates brain exercises to boost the user's cognitive abilities or motivates to do physical activities, such as sports, walking, or pursuing a hobby as found, e.g., in [1, 17, 30, 49]. The AC also supports the user with motivating comments and confirmation (e.g., [34, 49, 72, 103]), which shows appreciation towards the user and helps them enhance their physical and mental conditions.

5.4 Teachers and Coaches

A more persuasive AC type resembles the role of a teacher, trainer, tutor, or coach (e.g., [7, 8, 35, 107]). This type could be suitable for general and younger users in educational contexts (e.g., [8, 9, 32, 51, 88]) or health and fitness areas (e.g., [9, 11, 35, 107, 109]). ACs as teachers, of course, primarily show **educating** competencies, for example, by guiding the user in an activity or teaching a new skill (see, for instance, [4, 5, 8, 30, 65, 68, 109]). The added value for the user lies in the individualization of the learning process and personal support to reach a goal. Through teaching social skills, an agent could educate on coping strategies to counter negative feelings, like breathing exercises as Moxie or Emobie [5] teach their users. Next to these, monitoring and supervision competencies are also related to this type, which we described above (see Sect. 5.3) and show, for instance, in the educational companion iCat [79] who reacts nonverbally to the chess moves of his teammate, signaling good and bad decisions.

Interestingly, the last two roles show a slight shift in giving instructions. While the first two, assistant and friend ACs, align to the user's commands and behavior, both the caregiver and coach ACs, must convince their user to do something, which implies a turn in the commanding authority. Nevertheless, we argue this makes adaptation and engagement not less relevant to these types since considering the user's state and abilities are equally important to bring the user's actions to success.

5.5 Children and Pets

Lastly, we identified the role of a **child or pet** [13, 44]. These agents include ACs that resemble a child or animal in behavior [110], which trigger the user's need to take care of it. Dautenhahn [13] refers to this as the "caretaker paradigm" separate from the "companion paradigm". Still, we think both fit into our AC understanding since serving and receiving ACs must show adaptive and engaging behavior towards their users. In contrast to the other AC types, with the needy AC, we see another shift in the care duty towards a user taking care of an attention-seeking agent, e.g., through strokes, hugs, or ensuring the agent is well [13, 44]. The user, in turn, benefits from meaningful interaction, where their actions are seen and acknowledged by another entity. Hence, an AC dependent on the user shows them that their actions matter and creates meaningful interaction where the user feels needed [9, 45, 111]. Such ACs might be interesting to the general population to calm down and cheer up users in daily life - for which Emo or Qooboo are practical examples. In addition, we suggest this type is also useful for elderly and impaired people demanding interaction partners that are easy to engage with without time constraints, interesting for application areas like aged care, therapy or rehabilitation. Regarding the latter, Paro shows to be a good representant, especially since Paro's primary function is to respond positively to touches, which proves to increase the well-being of the users while fostering interactions between users at the same time as [66, 93] found.

6 Discussion

The goal of this review was to examine the communication and interaction design that is crucial in creating adaptive and engaging behavior in artificial companions (ACs). Our focus on the user's perception aligns with previous studies that highlight the importance of behavioral cues in the social design of an agent (e.g., [13, 16, 20, 34, 44, 45, 49, 72, 112]). Next, we will discuss our findings in a broader context, especially with regard to the research background that future work should consider:

6.1 Long-term Challenge of AC Development

Despite ongoing efforts to develop ACs, as demonstrated by multiple fictional, commercial, and academic examples (see Sect. 1.1), the implementation of the AC vision is a complex endeavor. This also becomes apparent in one-third of today's commercial ACs that have either failed in the market or remain prototypes [101, 113]. Studies exploring why users reject social home robots found that they failed to meet user expectations (e.g., [90, 91, 114]). Thus, in line with previous work, we see the necessity to continue studying user expectations towards ACs in different application scenarios (e.g., [100, 115, 116]) as well as directly involving users into the design process (e.g., [51, 60, 94]).

6.2 AC Ascription as an Interpretative Process

Attributing an agent as an AC occurs in the context of a continuing interaction characterized by positive experiences. This time component exposes the complexity of ACs as a research field with different stages in the companionship [61] that supposedly imply variations towards the design in different stages.Furthermore, since attribution as an AC depends on the user perception, recognizing adaptivity and engagement in an agent is an interpretative and therefore subjective process. A user might describe an appearing parasocial system as a companion without others agreeing nor comprehending to this attribution. We can observe such tendencies, for instance, among some users of robotic home devices, like vacuum cleaners or lawnmowers. Anecdotally, one of our students told us about her father, who showed appreciation towards its robotic lawnmower, calling it his "little fella". Most likely, developers of such devices do not explicitly intend for the companion ascription as functionality is more important than social competencies. But still, people form bonds with these agents. Based on our suggested definition (Sect. 3), we would reason such outliers by the user's individual interpretation of adaptivity and engagement in the agent's behavior. Although, we suspect that in these cases, the AC assessment will be robust only at lower levels of companionship (in terms of the complexity of the interaction). Consequently, edge cases like these imply a triad consisting of the design properties (agent), user characteristics (user) and specifics of the usage situation (context), along which we can describe and understand the interpretation process of an agent becoming an AC. Hence, the here presented findings on adaptivity and engagement remain to the agent's social design but do not allow conclusions on different user types or usage scenarios.

6.3 Influence of Cultural Context

Reflecting on ACs in an extended socio-cultural context, we must also involve the influence of cultural depictions, such as science fiction, on user expectations [58, 110, 114, 117–122] as well as on research and development processes [123, 124]. Hence, in order to construct adaptive and engaging ACs, future research should examine appropriate design configurations not only for specific user groups and scenarios but also within the cultural context in which the interaction occurs.

6.4 Implications for Potential AC Candidates

Furthermore, as we described at the beginning, we suggest ACs result from a design principle (the companion paradigm) that may be relevant for various social agents. However, due to a lack of usefulness, users tend to rely on conventional technologies than designated AC, e.g., when choosing established voice assistants over companionable home robots [90, 91, 125]. This could indicate that ACs compete with voice assistants in personal use cases. Instead, we would rather classify voice assistants as potential AC candidates in the type of a personal assistant and servant (Sect. 5.1). Hence, from the perspective of AC research, we argue that voice assistant users could benefit even more from their agent's capabilities if these expanded their adaptive and engaging behavior. This could show, for instance, in expanding the nonverbal communication features (e.g. different light patterns), tailoring communication styles to interaction situation, or sharing information based on the user's preferences and framing this as an successful learning process.

6.5 Essential Qualities of ACs

Reflecting at the empirical insights on designing social agents, we suggest that there is no one-size-fits-all approach to build agents as ACs (e.g., [23, 35, 100]). Different application areas, user types, and usage contexts require different combinations in the social design [32]. Our analysis summarizes potential variations of properties commonly discussed by academic research, which we suggest being essential in the design of many ACs. Although, as the specific implementation of these core design properties may vary among different ACs, our list is not exhaustive, and future research is encouraged to add and test features for different user types and usage contexts.

7 Limitations

We must point out the following limitations:

(a) Publication Bias: There might be a publication bias due to the systematic search process only including papers listed in Scopus and Web of Science. However, to lower the risk of a bias based on the databank, a manual hand search using Google Scholar expanded the search process. Still, the search results of the latter had to be sorted by relevance since Google Scholar displayed about 10,000 search results, which could not exhaustively be reviewed in this study. This means that papers with very poor visibility did not have a chance to get into the systematic sample. Also, the inclusion was limited to English papers. Furthermore, monographies, grey literature, as well as publications before 2000 were not considered in the selection process.

(b) Narrow AC Approach: Furthermore, we must note that we followed a narrow approach in the systematic search. This means, our search string only aimed for publications that explicitly include the companion term. Accordingly, our analysis did not consider papers with a similar understanding of assistive technologies but different wording. Nonetheless, the papers in the systematic sample allowed us to draft an AC definition. This first understanding delivered the basis for the extended non-systematical search we applied afterwards. Through the second step we were able to broaden our initial AC concept by papers that tend to discuss AC characteristics without directly referring to their technology as a companion.

(c) Quantifying Characteristics: As the systematic search yielded n = 540 papers related to the topic of ACs in the last 22 years, the selection had to be narrowed down to render the analysis feasible. Therefore, the FTS-scores (see Sect. 2) were utilized to create a ranking of papers. Through quantifying characteristics, only papers with an FTS-score of 8, 9, or 10 were considered for synthesis. Thereby, we assume that the higher the FTS-score, the more suitable a paper is for answering the corresponding research question. However, this could be a misconception as a paper may have a low score because it contains only a couple of statements, but these few statements could be relevant as well to AC research. Therefore, the selection according to the so-called high-relevance papers based on an FTS-score of 8, 9, or 10 means a cutoff criterion which creates a bias for papers with fewer statements and thus lower FTS-scores.

(d) Learning Effect: In addition, we realized a learning effect that needs to be discussed regarding the metrics in the initial selection process (FTS scores of 8, 9 or 10). When re-reading papers in the systematic sample, AC features were more easily identified based on the characteristics derived during this study. As a result, text passages that only implicitly refer to an AC quality could also be identified (e.g., recognizing and adapting to the user's emotional state is a more explicit property, whereas empathic behavior toward the user refers to the same quality but more indirectly). Hence, reanalyzing the systematic sample would result in more papers with a high FTS score, utilizing the identification scheme we derived within this review. Still, a random reanalyzing of papers revealed more papers with a high FTS score, however no major additional insights beyond the characteristics our analysis already revealed. This suggests that, despite this learning effect, our method is suitable for identifying relevant papers and approach our concept of interest.

8 Conclusion

In the present study, we systematically reviewed scientific papers explicitly addressing the companion term. Our dataset involves 22 years of research on defining ACs as a design concept and was combined from three databases extended by an additional hand search, through which our sample is characterized by a high degree of interdisciplinarity. Accordingly, our AC definition is not only systematically derived, but also integrates approaches from human–machine communication, human–machine interaction, robotics, affective computing, cognitive sciences, social sciences, etc. Given the continuously emphasized interdisciplinary nature of AC research [8–11, 13, 14], we can now present an equally interdisciplinary definition of the companion concept, which is the first contribution of this SLR. In summary we found two crucial AC characteristics: adaptivity and engagement. Our definition states artificial companions as social agents designed to adapt their behavior to different user and usage contexts. Artificial companions further aim to engage their users to form emotional bonds and (conceivably) build long-term human–machine relationships (see Sect. 3).

We assume a strong link between the communication and interaction manner and agents that are perceived as ACs by their users. Therefore, with the second research question, we analyzed different designs and gathered properties that are associated with ACs. These features can be categorized into five groups: adaptivity to the user, adaptivity to the usage context, engagement facilitating behavior, the agent's personality, and its appearance. The resulting compilation contributes to AC research efforts in two ways: a) It summarizes common design features that b) allow us to systematically test which cues evoke strong social responses and foster meaningful interactions between humans and machines (see Sect. 4). Accordingly, this study provides the theoretical framework to empirically investigate our guiding hypothesis of whether the communication and interaction qualities effect an agent to be perceived as an AC.

Furthermore, we would like to emphasize that our analysis demonstrated that there is no universal way to design ACs. Instead, we assume that from the here suggested compilation, some characteristics will be apparent in most ACs while others vary across AC types, and this brings us to the third contribution of this review. Within our last research question, we explored various AC scenarios and use cases aiming for an AC typology. We classified ACs according to the roles they might perform, associated competencies, user groups and application areas where we expect these types most likely to occur (see Sect. 5). Knowing full well that ACs are adaptable by nature, and the flexibility that comes with it might blur the lines between these types.

To conclude, we consider the findings in this review not to be finite but a proposal to identify and specify ACs, which is why future research is invited to add and refine this compilation in Sect. 4. We hope our synthesis helps researchers and developers to explore ACs and delivers a common starting point for the communication and interaction design of social robots, voice assistants and digital avatars that strive to become artificial companions.

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Declarations

Conflict of interest The author has no potential conflict of interest. Furthermore, the author certifies that she has no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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