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What a Vision: The Artificial Companion

A Piece of Vision Assessment Including an Expert Survey

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Abstract

Our approach to vision assessment combines discourse analysis and an empirically oriented sociology of knowledge approach. The main piece of the empirical research on the artificial companion (AC) vision was a survey of AC-researchers from European AC-projects. Further, the scholarly literature and self-descriptions of European AC projects were analyzed. The findings reveal in which respect and to what extent the AC can be regarded a vision, and allow addressing the pending tasks to be completed by Technology Assessment (TA) – the perspective from which this article was written.

At the R&D-level, the vision to bring about artificial companions serves as a distant horizon supporting the attempt at organising a new interdisciplinary strand of research, to which scientific communities with rather different ambitions are meant to contribute, in particular those related to service robotics, social robotics, virtual agents, artificial intelligence, ambient intelligence, and human-computer-interaction. The semantic analysis of the companion metaphor reveals its usefulness addressing artefacts which are present long-term in a personal environment and which are at the same time somehow useful. If taken literally, however, the companion metaphor becomes misleading as the artefacts under construction do not fulfil the prerequisites of companionship. Overstretching the metaphor may, nevertheless, serve to stimulate the public debate about these technologies.

Although we regard artificial companions as "new and emerging technology" we would hold that AC development is advanced enough to be subjected to an ordinary Technology Assessment: It should be possible to assess the state of the art along the criteria of the research field itself (e.g. adaptivity, autonomy and interactivity of the artefacts) and along the criteria of particular application fields (goal attainment, efficiency, unintended consequences etc.). TA can proceed as usual investigating the multiple actors' resources, perspectives, preferences and interests. In this context the issue is no longer a particular vision, but the overall socio-technical futures discourse. TA is able to contribute to this discourse.

1 Introduction

The career of the "companion" metaphor in robotics research, the debate about "artificial companions" (AC) as assistive technology in health care and the appearance of companion robots as protagonists in movies like "Eva" (2011), "Robot and Frank" (2012), or the TV series "Real Humans" (2012) have raised the question of whether the AC qualifies as a (guiding) vision relevant for real world innovation processes. Therefore we conducted an empirical vision assessment focusing on the level of European AC-research and development (R&D). For reasons of socio-cultural homogeneity we deliberately limited the scope of the investigation to the European discourse maintained by researchers involved in European research projects.

The first piece of the vision analysis presented addresses the question of whether there is a relevant corpus of scientific literature on the subject and a relevant number of research projects. If not, there would be no use in further analysing it. In the second step we look at the self-descriptions of 17 AC-projects to get a better understanding of what types of artefacts for which purposes are under development in the field of European AC research.

The main piece of research presented is a survey of researchers working on the projects selected. Researchers were confronted with statements and questions addressing the content of the AC-vision, competing terms, the state of the art, the time horizon of the development process, and the technical core of companion systems, i.e. their defining characteristics. Researchers widely used the opportunity to comment the statements providing us by this with valuable insights into the AC discourse of European developers. The answers of the experts may be read as a fragment of the current European developers' discourse on the artificial companion. Methodologically, we regard this interchange between developers and TA-researchers as a piece of "participatory analysis" (Fischer 1993).[1]

Together these three pieces allow us to clarify in which respect or to what extent the AC can be regarded as a vision and why this is true only with reservations. Based on this assessment we are able to sketch future tasks for technology assessment on this subject matter. To better understand our approach in the context of TA we start with some conceptual and theoretical considerations in the next chapter.

2 Theoretical considerations

The purpose of this chapter is to outline our approach to vision assessment, to connect it to earlier approaches, and to introduce the concepts we will use. In our view it is promising to combine discourse analysis and the sociology of knowledge. Discourses related to innovation processes and socio technical constellations are termed "socio technical futures discourse" here, short STF-D. Further a distinction between a topic of an STF-D and a "vision" is proposed. The analysis of discourses is an indispensable exercise within Technology Assessment (TA) and may in some cases include a vision assessment. Hence we start defining TA and its nexus to vision assessment.

2.1 TA and vision assessment

Technology Assessment is concerned with scientific and technological developments, inventions and innovation processes from the point of political relevance. Technology Assess-

[1] The focus of participatory analysis is on participatory social science methods as a means to enrich and to inspire scientific TA analysis. Its ambition is different from participatory TA (pTA) if understood as a democratic procedural step in its own right in the context of technology governance.

ment (TA) can be defined as scientific analysis of dynamic and complex socio-technical constellations carried out with the intention in mind to advise policy and to contribute to public discourse. TA is an activity within the science system, the recipients of its outcome, however, are both, the political system *and* the public sphere. TA is located within the loop of public perception of problems and their political processing (cf. Imhof et al. (2011: 14-15) for the nexus between public sphere and policy). The results of TA constitute a specific type of input to the ongoing discourse, which we will address more specifically as socio-technical futures discourse.

The analysis of socio-technical constellations implies the investigation of the multiple actors' resources, perspectives, preferences and interests, and, furthermore, a reflection on the process dynamics, which includes among others to look into unintended consequences, social mechanisms, and systemic risks (cf. Gloede 2007: 52). The analysis may also turn to those imaginations and imaginaries, and especially visions, which are likely to influence the innovation process. In one or the other way, (guiding) visions have been a research topic at least since the 1980s, when the idea caught on that imaginations about the future, i.e. about future socio-technical constellations, are extremely relevant in the context of socio-technical innovation processes. And that the analysis and assessment of these (guiding) visions might help to better understand the dynamics of innovation processes.

"Vision assessment" was already discussed as a useful exercise in the 1990s (cf. Dierkes et al. 1992, Hellige 1996, Giesel 2007: 176-178). It has gained new momentum however since the turn of the century (cf. Grin/Grunwald 2000), when the focus shifted to visions as outreaching pictures of the future, e.g. NBIC convergence with its envisaged developments of nanotechnology, biology, information technology and cognitive science (Roco/Bainbridge 2002). Today the assessment of guiding visions, techno-futuristic visions (Coenen 2006), technology futures, socio-technical imaginaries and the like is *en vogue* again.[2]

From a sociological perspective vision assessment can be understood as a practical and integrated application of both, (epistemic) discourse analysis and (actor oriented) sociology of knowledge. These two references are clearly apparent in the definitions of what a "vision" is. To give but two examples:

Roelofsen et al. define:

> "Visions can be described as mental images of attainable futures that are considered desirable and shared by a collection of actors. These images guide the actions of, and the interactions between, those actors" (2008: 338).

Giesel, after having scrutinized the scholarly literature, comes up with the following definition that many scholars working in the field are assumed to share:

> "In technology studies guiding visions are understood as steady imaginations about technical futures which are at the same time deemed feasible and desirable, and which shape the thinking and acting of the actors"(cf. Giesel 2007: 162, translation ours).

The "sociology of knowledge approach to discourse" as proposed by Keller (2011) is one approach backing our considerations.[3] It is worth mentioning that the approach is open for empirical social research of actors and groups of actors, and will often even require it.

[2] See for instance the fresh approaches of Gleich et al. 2010a and b, Grunwald 2012, and Schulz-Schaeffer 2013.

[3] Depending on purpose, further approaches to discourse analysis may be become relevant for vision assessment (cf. Viehöver et al. 2013).

2.2 Socio-technical futures discourse

We term the specific discourse, which is an integral part of socio-technical constellations and innovation processes, socio-technical futures discourse. This expression builds on Grunwald (2012), who introduced "technology futures" as a broad concept able to cover a broad range of descriptions of the future.

Under the umbrella of this term there is room among others for "far reaching visions" and mundane (guiding) visions very close to technical specifications. Often we will find that a vision contains both, references to present artefacts and how to design them as well as imaginations of artefacts in the far future which are presented as feasible then. "Artificial Intelligence" or "nano-technology" may serve as examples where references to ready available instances of the technology coexist and are combined with futuristic socio-technical imaginations.

STF-Ds have some specific properties. What is essential for this type of specific discourse, is its reference to the *future* and to *technology*, and moreover its focus on both *feasibility* and *desirability*. The two latter elements were already present in the definitions of "vision" quoted above. They are also present in similar concepts such as "sociotechnical imaginaries" introduced by Jasanoff and Kim (2009) when analyzing specific science & technology policy discourses in which attainable futures (feasibility) and politically prescribed futures that ought to be attained (desirability) are present at the same time (2009: 120).

An STF-D might be regarded as a dynamic discursive formation (Keller 2011: 47 with reference to Foucault), which depends among others on the evolving state of the art of the technology, changing innovation networks, and the reach of discourse. It is obvious that the development and deployment of a technology, the state of the art, and the experiences with instances of a promised technology influence and change the discourse about "feasibility" *and* "desirability" of a technology. Weyer (1997) has convincingly argued that at different stages of an innovation process, a different constellation or network of actors is required to maintain the innovation process which again goes together with adjustments or even transformations of the initial STF-D.[4]

Talking of "stages" and "levels" of STF-D is of course a heuristic simplification aimed to provide a preliminary structuration schema. At a certain stage of the innovation process the STF-D leaves the R&D sphere (university–industry–government relations; cf. Etzkowitz/Leydesdorff 2000) and extends to particular application fields. This takes place at the latest, when the new technology is about to be deployed and implemented. Then the demands and requirements of specific application fields become part of the discourse. At this level the "non-feasible" and the "non-desirable" will be addressed anew.

Sooner or later, the STF-D also extends to the public sphere, where the STF-D will be broadened, reshaped and modified through public debate. Both, the public debate and the more specific debates related to particular application fields are places for contestation: the "non-feasible" and the "non-desirable" (and all options in between) become part of the discourse and transform the initial narrower STF-D. Lösch (2006) has shown that requirements stemming from the different functional subsystems of society are fed into the public discourse bringing about important adjustments and changes of the STF-D.

The extension of the STF-D from the R&D level of discourse to specific *application fields* and to the *public*

[4] Along these lines Böhle (2003) investigated "digital cash" as a guiding vision, which was frustrated in the course of a failing innovation process.

sphere implies a twofold problem orientation and this raises the attention of TA.

2.3 Topic and vision

A discourse has to be about something and this something is its *topic*. The perception and distinction of something by many as a *topic* is already the result of previous actions and communication acts. In this view a *topic* is already a specific qualification of a socio-epistemic phenomenon which emerged as the result of numerous communications and turned into a reference point for further discourse contributions. It indicates attention and attracts attention.[5] This is of course valid for any STF-D. An established topic of discourse is like the top node of a referral system with interrelated discourse fragments unfolding its content, elaborating it, contesting it, modifying and transforming it. As stated above, the main dimensions around which the STF-D revolves are future, technology, feasibility, and desirability. It is not possible to analyze a topic separated from the discourse in which it emerged and in which it will be transformed. The same is true for "visions".

In contrast to a topic of discourse, which is like a neutral indicator, a vision in the context of an STF-D is like a future statement declaring this or that will happen and it ought to happen. For example, introducing the expression "ubiquitous computing" may want to say computing will be everywhere, but as a vision statement it comes with the normatively positive connotation that "ubiquitous computing" *should* take place and that efforts *should* be made to make it happen. Other vision statements of very different content are for instance, "shaping the world atom by atom", "100 % renewable", "one laptop per child", or "social robots". They are all imperatives: Let there be x! Vision statements are therefore innovation statements related to and put forward by their proponents. Any vision in this innovation context needs to have at least some degree of public presence and proponents advocating it. Visions need to be propagated and to be made explicit by their proponents. As with the STF-D in general, the elaboration of a vision and its legitimation can go beyond the R&D level and enter the public sphere and specific application areas where the problem solving capacities of a new technology will be under discussion.

There are several tasks a sociology of knowledge approach to vision assessment should address. One starting point could be the analysis of documents exclusively devoted to spelling out a particular vision with all its ambitions, promises, and statements of utility, mission and legitimation. Next, an analysis of its diffusion and resonance – beyond the initial promoters – could be performed. This task could be described as studying the career of a vision within an STF-D, its transformations and its formative power in the context of an STF-D. Further analysis of a vision, however, would have to go beyond linguistic and semantic analysis and turn towards the actors propagating a given vision as desirable and assess the volition and power behind a vision and its capacity to shape or guide thinking and acting. To achieve this, the sociology of knowledge approach can make use of empirical sociological research.

[5] Mambrey et al. (1995: 33-37) proposed to regard Leitbilder (guiding visions) as "symbolically generalized communication media", while Lösch holds that especially "futuristic visions can function as means of communication" (2006: 105), and Grunwald (2012) regards technology futures as "media of communication". We feel the temptation to turn topics of discourse into media of communication, but for the time being we resist. Regarding the AC we feel uneasy to do so, because in a way understanding visions as media runs the risk to prematurely turn an *explanandum* into an *explanans*.

3 The AC as a topic of research and research policy

The rise of the companion metaphor can be dated back to the beginning of the century.[6] In 2002, Sherry Turkle contributed to the famous report on converging technologies (Roco/Bainbridge 2002), funded by the National Science Foundation (NSF), hinting at a new metaphor for computers "when the computer is not a tool, but a companion" (Turkle 2002: 133). As a sociological term she proposed to talk of "relational artifacts" (ibid). In the same year a colleague of hers at the Massachusetts Institute of Technology (MIT), Cynthia Breazeal, published the first book about the related topic "sociable robots" (Breazeal, 2002).

In order to show the career of the research topic we searched a major scientific database (Scopus). The search combined the "artificial companion" and various similar terms. 1,722 documents were retrieved.[7] The graph (figure 1) confirms that more or less from the year 2000 onwards the terms chosen are increasingly used in scientific literature.

Adding "social robots" as a further optional search term, the number of relevant documents increases to 2,967. Given that Scopus is of course not comprehensive, the figure indicates remarkable research activities, but not yet a broad field of research like "Artificial Intelligence", for which the same database yields some 80,000 records per year (86,225 in 2012).

It can further be shown that the "artificial companion" is propagated at the level of R&D-policy and by related research projects. In the European Commission's ICT online presentation of its work programme 2013 (part of FP7) one of the declared aims of the Commission reads as follows:

> "We want artificial systems to allow for rich interactions using all senses and for communication in natural language and using gestures. They should be able to adapt autonomously to environmental constraints and to user needs, intentions and emotions" (EC 2012).

In the context of the EC's Future and Emerging Technologies (FET) flagship competition one of the six "FET-Flagships Preparatory Actions" funded was about "unveiling the secrets underlying the embodied perception, cognition, and emotion of natural sentient systems and using this knowledge to build robot companions based on simplexity, morphological computation and sentience…" (EC 2012:168).[8]

The companion vision is also present in a programmatic form in a German long term project "A companion technology for cognitive technical systems" (SFB TRR 62) funded by the DFG, the biggest German research funding organization. It started in 2009 and will run at least till the end of 2016.[9] There the vision reads as follows:

[6] It would be possible to set an earlier starting point if for instance research on "affective computing" (e.g. Picard 1997) or "humanoid robots" in general were to be included.

[7] The Boolean query was: ALL ("robot and friend" OR "companion robot" OR "artificial companion" OR "relational agent" OR "relational artifact" OR "socially intelligent robots" OR "socially interactive robots" OR "socially assistive robots"). The term "socially intelligent robots" is used e.g. by Dautenhahn 2007, "socially interactive robots" by Fong et al. 2003 and also Becker et al. 2013: 52, "relational agents" by Bickmore et al. 2005, and "socially assistive robots" by Allison et al. 2009.

[8] The project referred to in the EC's working programme was called "Robot Companions for Citizens", RoboCom for short (http://www.robotcompanions.eu/). Its vision is presented by the consortium in Dario et al. 2011. Although the research program proposed by RoboCom was not selected for further FET flagship funding (January 2013; cf. EC 2013a), the artificial companion will remain a prominent topic despite this setback (cf. EC 2013b).

[9] Cf. http://www.uni-ulm.de/home2/presse/aktuelles-thema/sfbtransregio-62.html for the funding decision of December 2012.

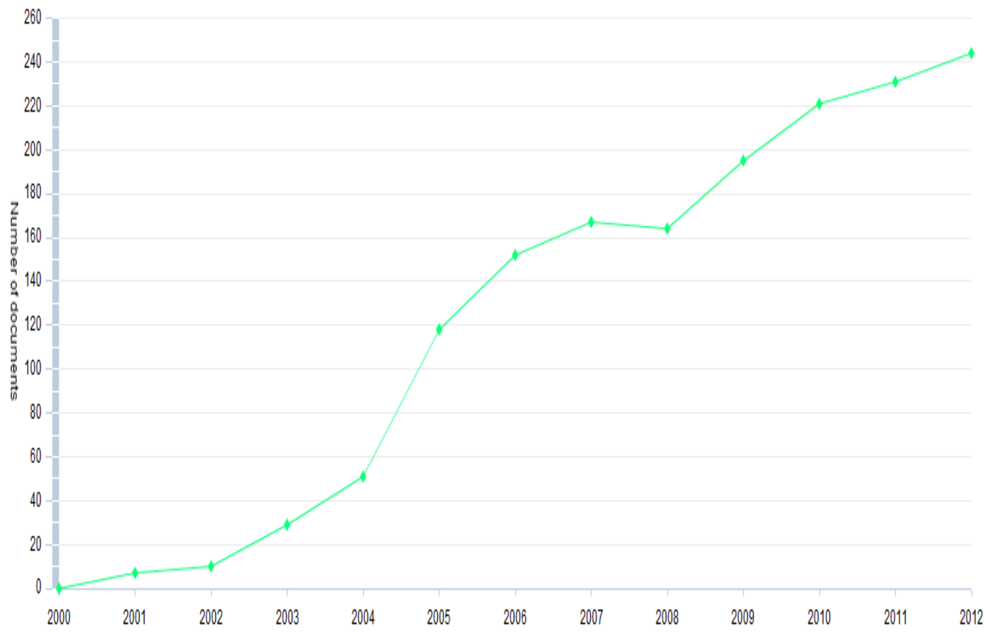


Figure 1: The rise of the companion metaphor in scientific literature

Legend: This figure has been calculated with an analytical tool of Scopus (09.09.2013)

"Technical systems of the future are Companion-systems – cognitive technical systems, with their functionality completely individually adapted to each user: They are geared to his abilities, preferences, requirements and current needs, and they reflect his situation and emotional state. They are always available, cooperative and trustworthy, and interact with their users as competent and cooperative service partners" (Wendemuth/Biundo, 2012: 89).

Following a vision statement by Dautenhahn (2007) socially interactive robots should exhibit the following characteristics:

"… express and/or perceive emotions; communicate with high-level dialogue; learn models of or recognize other agents; establish and/or maintain social relationships; use natural cues (gaze, gestures etc.); exhibit distinctive personality and character; and may learn and/or develop social competencies" (2007: 686).

The quotes highlight a common long-term research agenda with very ambitious goals, and a certain undecidedness about the appropriate term to express the vision.

In order to identify European AC research projects, we searched the Internet and several professional databases. It was decided to limit the geographical scope to Europe assuming a common cultural background and a common funding context. This concentration on Europe should later enable coming up with findings relevant for the European discourse on ACs. The most important database for this purpose was CORDIS (The European Research and Development Information Service). Apart from two exceptions, the projects identified belong to the 6th and 7th European Commission Framework Programme (FP6, FP7) running from 2002 to 2013. In the end, more than 40 AC projects were identified.

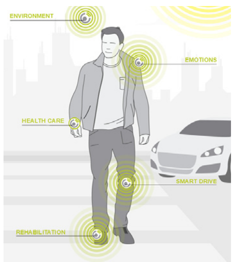
4 Artificial companion typology derived from projects' self-descriptions

From more than 40 projects identified 17 were selected for closer examination (Appendix II). The selection process was not straightforward and went through several iterations. First, we wanted to select those AC projects which included health care for elderly as an envisaged application field. Then we thought it to be more interesting for our purpose of vision assessment to broaden the range to possibly embrace the whole variety of companion projects. So we picked up further projects. This way 15 FP6 or FP7 funded projects were chosen: ACCOMPANY, ALIAS, ASTROMOBILE, COGNIRON, COMPANIONABLE, COMPANIONS, DOMEO, EXCITE, FLORENCE, GUARDIAN-ANGELS, HOBBIT, KSERA, LIREC, SEMAINE, SERA. In order to cover the whole range of projects using the companion metaphor and to cover the diversity of use cases, we then added two national (German) AC projects: The project FRIEND which targets exclusively physical support and the project SFB TRR 62 which aims to implement companion-features in technical systems such as ticket machines.[10] These projects also correspond to the companion vision as expressed in European policy documents.

Hence, the projects chosen (Appendix II) cover very different companion technologies ranging from mobile robots to virtual agents, from pure monitoring systems (e.g. “Guardian Angels”) to physical (e.g. “Friend III”, “RobuWalker”), cognitive (e.g. “Hector”, “Cognitive Robot Companion”) and social supportive assistants (e. g. “Florence robot”) as well as conversational companions (e.g. “Samuela”) or artificial playmates (e.g. “Pleo”, “iCat”), from quite simple low-cost telepresence devices (e.g. “Giraff”) to very complex and expensive multifunctional robots (e.g. “Care-O-Bot 3”).

The analysis of the chosen projects based on the projects’ self-descriptions has revealed that companion technologies are meant to deliver three types of service: *monitoring services, personalised assistive services* and *companionship services*. Even if most of the systems combine the different types of services, it is possible to classify them drawing on the dominant function. It is proposed to distinguish artificial companions as (1) *Guardians*, (2) *Assistants* and (3) *Partners*.

4.1 Companions as Guardians



GUARDIAN ANGELS project
http://www.ga-pro ject.eu/ project

This type of companion system focuses on *monitoring services*. Like the Victorian chaperon (Wilks 2009) these companions should accompany and supervise the user while monitoring his or her health status and environmental indicators (e.g. room temperature, pollution). These companions, monitoring and controlling what happens at home (e.g. sensor based emergency alarm, central control of home electronics), have a strong link to AAL technologies (ambient assisted living). Meyer et al. (2009) envision a scenario like this:

> “Like a good nurse, the robot can continuously observe and monitor the activities of the user. In a long-term view, this allows to provide valuable data for a long-term assessment and to detect changes in behaviour that might indicate a decline in the overall health state, e.g. reduced mobility. On a daily basis, the robot can be the personal coach of the user, detecting e.g. that there have been only pretty limited physical activities this day and encouraging to do some training” (Meyer et al. 2009: 4, FLORENCE).

In the GUARDIAN ANGELS project the functionality is not incorporated in a robot but in a series of wearable devices. The main function of these devices is to monitor physical and physiological parameters of the user and his or her environment (e.g. blood pressure, hydration level,

[10] Reconsidering this selection procedure we come to the conclusion that a comprehensive coverage of all FP6 and FP7 funded companion projects and a strict limitation to these projects would have been preferable because of its greater coherence. Proceeding like this, also the following projects would have been included: aliz.e, BRAID, IROMEC, MOBISERV, MOVEMENT, paco plus, RCC RoboCom, robots@home, script and SRS.

stress, air quality, information for blind persons). These computational devices are permanently in operation but remain invisible in the background, hence guardian angels. GUARDIAN ANGELS are companions in the broad metaphorical sense as "invisible helpers" continuously accompanying the user.

4.2 Companions as Assistants

"Hector"
http://www.metralabs.com/index.php?option=com_content&view=article&id=77&Itemid=59

Assistants are helpers providing *personal assistive services*. In contrast to Guardians the user is enabled by an Assistant to fulfil tasks, which she or he would otherwise be unable to perform. The emphasis of these companions is not on supervision but on enabling. These services may be provided either autonomously by the companion system, based e.g. on data sensed and processed, triggering the computer's behaviour, or initiated on-demand by the user (Cavallo 2011: 5328, ASTROMOBILE). In order to provide appropriate assistance the robot should be able to continuously adapt to the user's behaviour. Therefore learning capabilities are important: "The robot is not only considered as a ready-made device but as an artificial creature, which improves its capabilities in a continuous process of acquiring new knowledge and skills" (COGNIRON Appendix III).

Usually, in this type of companion project it is also required, and highlighted as a major research challenge, that the man-machine-relation has to resemble somehow elements of social interaction standards. "Thus, it isn't sufficient anymore for (domestic) robots to perform useful tasks or to have useful functions. Domestic robots also must be able to perform them in a socially acceptable manner" (Correia et al. 2008: 4, LIREC). Companions have to "appear as competent and empathic assistants to their user" (SFB TRR 62 Appendix III).

The most common task for these assistants is *cognitive support*: helping to remind. Services of this kind include agenda planning, medication reminding, drinking protocol, memory games and therapy. In the COMPANIONABLE project for instance companion robotic systems are seen as therapy management platforms. In collaboration with a smart home system the mobile robot "Hector" monitors the user's state and the facilities in the house (door, oven, and refrigerator). And then it gives verbal reminders and recommendations like "I am afraid you forgot to switch off the oven!" or "I can see you are bored. How about doing a little of brain training?" (Companionable Consortium 2009). Obviously conversational abilities are required even for the purpose of effective disease self-management (KSERA, Pol et al. 2010).

Apart from physical and cognitive support, assistants can also serve as *communication intermediaries*. In this case ACs are intended as means of computer mediated communication enabling multi-modal telepresence to ease social inclusion and to reduce the sense of loneliness (e.g. "Giraff", EXITE, Cesta et al. 2010). The objective is to "keep the user linked to the wide society and in this way to improve her/his quality of life" (ALIAS Appendix III, Rehrl et al. 2011). Most physical services provide stand up and walk assistance (e.g. "RobuWalker", DOMEO, Sarr 2011). If the system is equipped with a robotic arm it can also grasp and carry objects (e.g. "Care-O-Bot 3", ACCOMPANY, Graf et al. 2009). Assistants of this type are often meant to support disabled people in their everyday life.

4.3 Companions as Partners

ACs as *Partners* appear as conversational vis-à-vis, artificial playmates and interdependent actors. The emphasis shifts from monitoring and assistance to *companionship services*. This implies a design focus on interactivity and relationship – even more than in the case of companions as Assistants performing functional features.


"Poppy" SEMAINE Project
http://semaine-project.eu

These types of companions are designed to exhibit emotional expressions (through voice, mimics and gesture), and vice versa may track the user's emotional state to adapt accordingly. For example the SEMAINE project invented virtual agents for *conversational interchange*. The so-called "Sensitive Artificial Listeners" are programmed with different characters and individual behaviour e.g. the polite "Poppy" or the more aggressive "Spike" (Douglas-Cowie et al. 2008, McKeown et al. 2010, SEMAINE). Companions are seen here as artificial personalities for a daily chat about everyday matters and personal feelings.

Artificial playmates (e.g. "iCat", LIREC, Correia et al. 2008) rely on personification technologies as well, but focus on fun and games. With speech and emotional face expressions the companion shall provide empathic feedback while playing games. Considering the AC as research tool the game dimension provides an ideal context for exploring the human-companion relationship (LIREC Appendix III, Correia et al. 2008). Furthermore, games are suitable for cognitive stimulation and the transfer of knowledge and skills.[11]

Another design idea is to provide for interdependent partnering. This concept is present in European projects as *mutual care* and *co-learning*: "By providing a possibility for the human to 'take care' of the robot like a partner, real feelings and affections toward it will be created" (HOBBIT Appendix III, Lammer et al. 2011). The social robot is imperfect by design and behaves more like a clumsy dog than a perfect butler or servant. With this approach the acceptance of robot assistances shall be increased. The concept of co-learning assumes that the robot and the user are providing mutual assistance. The user shall not be dominated by the technology, but empowered, physically, cognitively and socially (ACCOMPANY Appendix III).

Bottom line: This typology is focusing on the services Acs are aimed to deliver. Behind AC services are AC technologies. In technical terms AC technologies are a combination of control technologies (monitoring, medical observation, surveillance, and ambient intelligence), human-computer-interface design, technologies for assistive systems, and programmable communication media (Zhao 2006; Sugiyama and Vincent 2013). The AC thus denominates an interdisciplinary field in which rather different types of artefacts can be developed and to which different scientific communities contribute. It remains to be seen in how far they share a common vision.

5 Survey of European companion experts

The survey addressed researchers from the 17 projects selected sending them a questionnaire. As already mentioned it was decided to limit the geographical scope to Europe, assuming a common cultural background and a common funding context. Apart from two exceptions the researchers were involved in FP6 or FP7 projects. This concentration on Europe should

[11] This approach can also be found in the literature on "Serious Games" (e.g. Michael/Chen 2006).

simply enable to come up with findings relevant for the European discourse on ACs.

Methodologically, the questionnaire was constructed similar to an explorative, guideline-oriented expert interview (Kruse 2007: 164-184). The recipients were confronted with statements and had a multiple choice to answer spontaneously and a free field to explain their choice or to articulate discontent with the statement. After a pre-test phase, the questionnaire was sent in September/October 2012 via E-mail to the project coordinators and if necessary to other researchers from those projects. At the end of the day we received filled questionnaires from all 17 projects. From two projects we received two questionnaires so that the sample covers 19 experts. Among the experts were only two women. The disciplinary background of the experts ranged from computer science (4) and electrical engineering (3) to physics (1), mathematics (2), psychology (3), education science (1), biology (1), bio-engineering (1), biomedical engineering (1), industrial engineering (1) and nanotechnology (1).

Asked which terms (out of ten) they would regard as proper descriptions of their research field, 18 respondents checked "assistive robots", 14 "companion robots", 13 "service robots", 11 "cognitive robots", 11 "social robots", 10 "companion technologies", 5 "virtual agents", 5 "Ambient Assistive Living", 3 "emotional robots", and 3 "sentient machines". Further, we asked what term they normally use to describe their field of work. The answers overlap with the former ones, but were in some cases more specific with respect to particular research aspects of companion technologies (e.g. man-machine interface, sensors and sensor networks). We have no doubt that all respondents are indeed artificial companion experts.

The questionnaire addressed the "companion" as a (guiding) vision in general (5.1), and then (5.2), if a shared understanding of essential properties defining a companion system existed. At the same level of R&D we further wanted to know (5.3) about the focus of research and the research ambitions. Finally (5.4), we investigated if and in which way the vision of an AC is influencing the concrete artefact design.

5.1 The overall vision and its time horizon

The first statement the nineteen experts were asked to consider was about the companion vision in general:

"Machines helping and assisting humans in the broadest possible sense is the core vision behind *artificial companions*. At this visionary layer, the companion metaphor brings together the assumption that robots (and other intelligent artefacts) will enter and populate our daily life, and the expectation and demand that these artefacts should behave 'human-friendly' like *companions*, friends, servants etc."

Fifteen marked "Yes, I agree that this is the overall vision behind the 'companion' metaphor", four marked "No, I would rather disagree". Ten respondents gave comments. Most comments were intended to specify and clarify the statement and to resolve possible ambiguities, three comments were clearly opposed (Table 1).

The modifying comments tend to underline "social relation" and "human-like interaction" and "companionship" as important characteristics of the AC vision. Those, who disagree with the statement either underline the character of the technology as a means to an end (task-orientation, machine character of technology, ACs as servants) or they broaden the scope of the vision to intelligent artefacts in general including for example intelligent buildings or smart devices. This disagreement comes as no surprise when regarding the type of intelligent artefacts developed in these projects (an intelligent wheelchair,

Table 1: Selected comments on statement one

Comments modifying the statement	Comments opposing the statement
Robots can enter our lives where tasks are physically overdemanding, or time consuming or boring / not human friendly. Particularly in care this could allow more time for personal interaction (ALIAS). A companion is an agent you have a social relation with just like a pet or a friend, but unlike a servant (KSERA).	Our experiences are that robots are designed to support people and to do tasks which cannot be done by the people anymore or tasks which are too "heavy" to do. Then they are accepted by the people. Furthermore we made the experience that robots should not look human-like. They should stay a machine and do their tasks reliable and with a high success rate (FRIEND).
I agree but would choose a more specific definition. "Human-friendly" is a quite abstract definition in my opinion. For me a companion would in particular include the possibility of human-like interaction and communication (ASTROMOBILE). We are not setting out to replace humans but to provide new technologies to help them (LIREC).	In my opinion our companions will be rather intelligent systems surrounding us, not robots. Both, systems installed in our surroundings (e.g. buildings, infrastructure, etc.) and in our clothes or on us. Robots will be part of this vision however not the most important (GUARDIAN ANGELS).
The core behavior of such an agent should be to be "companionable" (COMPANIONS).	A Companion is for me like a servant (not a friend) (SFB TRR 62).

wearables, interfaces to e.g. ticket machines).

The second question was about the potential social impact of ACs in the future and the time horizon when this might happen:

"It is expected that the massive deployment of *artificial companions* will radically change society. That's apparent e.g. in the envisaged EU-project "Robot Companions for Citizens" as well as in the thinking of sociologists like Dirk Baecker, who assumes that it will take new structures and a new culture for the next society in which humans and intelligent artefacts are co-present and communicate. Do you think that the advent of *artificial companions* will happen and deeply change Western societies in the not too far future (10 to 15 years)?"

Twelve marked "Yes, I think so, but it will take many more years until a profound societal change will be observed." This means 15 years and more. Five agreed to the default of 10 to 15 years. One respondent expected that "it will take less than five years until a profound societal change will be observed" and another one did not expect "a major societal change from companion technologies" at all. Ten respondents added comments (Table 2).

Table 2: Selected comments on question two

Those assuming a time horizon of 10 to 15 years commented…
I think artificial intelligence in general will deeply affect society (not only Western). The time frame is difficult to say, but I see a lot of progress being made in the last 10 years […]. Artificial Intelligence will become a major industry, comparable to the computer industry in the 80-ties and 90-ties. […] (FLORENCE).
Robotic agents are entering the houses of people. Mostly domestic robots are still in the research phase. The major breakthrough that is missing is intelligent social behavior. If this happens, and research is on-going, the only obstacle left for widespread adoption is a societal change where people think of robots as part of society (KSERA).
The question is how these changes will look like. Artificial companions change the way we communicate, the way we search for information, the way we interact with each other

(or more general with our environment), i.e. this might radically change a lot of things we are used to. Due to the rapid change in technology there will not be "one" change, but a constant adaptation following recent technological advances. Nowadays, the direction of these changes is not clear to me… (SEMAINE).
Those assuming a time horizon of 15 years and more commented…
There are many things to do before stable artificial companions can really serve in different use-cases. Beside the development of useful and stable use-cases, the financial issue will be a very important thing for this development (ASTROMOBILE/1).
I think that the society could really change in several aspects with the advent of artificial companions. Looking at the progress and advancement of robotics in the last 20 years, I think that it will happen not before 15-20 years. However if some disruptive enhancements in robotic technologies happen, then it is likely that societal changes can occur also before 10 years. (ASTROMOBILE/2).
It depends on definition of artificial companions (we already are accompanied by smart phones, reminding us and supporting us in our communication e.g. via facebook…) (ALIAS).
There are clear technological and financial barriers to be overcome before useful and widespread uptake is likely to make an impact (LIREC).
The technical challenges are immense, and easily underestimated. It is not yet clear just what level of capabilities will enable an artificial companion to provide the level of autonomous support that users would expect. It is very important that the research community doesn't overhype the technology, otherwise there will be huge disappointment (and reduced funding). For example, it is often assumed that communication with such an agent will be via spoken language, yet it may be 50 years before we know how to create a "usable" and "useful" general-purpose spoken language interface (COMPANIONS).
The problem at the moment is that the robots are not reliable and there are no "cheap" solutions which improve the life of the humans significantly (FRIEND).
The societal changes will be initiated after some 10-15 years […] (GUARDIAN ANGELS).

The comments show that, independent of the time frame chosen, most researchers assume that it will take more than ten years before research will have led to widespread applications changing society. At the present stage of basic research in many cases the technical challenges are at the fore and still immense. Nevertheless, AI may advance rapidly, and some disruptive enhancements in robotics technology may occur. Financial issues, which might include robust business cases for these new technologies, are another issue not yet resolved. At this stage of research it is obviously too early to anticipate and inappropriate to speculate about the future social impact of companion technologies.

If the AC metaphor is used in the broader sense, then companion systems (e.g. smartphones) are already in place. In a similar way we can understand why the expert of the EXCITE project did not expect a major societal change: Because the technology developed in this project is already there and close to available technologies (video telephony in this case).

5.2 Crucial properties of companion systems

Researchers were asked which properties they regard as necessary, improving or irrelevant when defining ACs. We presented nine properties to check (Table 3).

There is no single property regarded as necessary by all experts. But there are some properties selected by about two thirds of respondents. *Sensing, learning* and *adaptation* are the three capabilities more than two thirds of the experts regard as necessary followed by a *multi-modal interface* and

Table 3: Crucial properties of companion systems

The artificial companion must…	neces-sary	improv-ing	irrelev-ant
have a multimodal interface	12	7	0
have sensors sensing the user	14	5	0
be physically embodied	3	12	4
be designed as a personal artefact (e.g. my device configured by and/or for me; my PC, my PDA, my pet, my smartphone, my companion …)	11	8	0
be provided with an anthropomorphic (or zoomorphic) shape	01	8	10
be able to adapt its behavior according to dynamically changing information about its user	13	6	0
be able to learn from former interactions	14	5	0
be autonomous in the sense that it can operate for a longer time without trained personnel present	12	5	2
be able to simulate at least a certain degree of "personality" by e.g. simulating feelings, sophisticated conversation strategies, expressing disagreement	9	8	2

autonomy. Those who did not regard these properties as necessary regarded them as improving the qualities of the AC. We would assume that the core capacity of an AC to be discerned is its *adaptivity* based on continuous feedback from its environment.

The fact that just one respondent declared an *anthropomorphic* (or *zoomorphic*) shape as a necessary property, while 10 regarded this feature as irrelevant, may come as a surprise. An explanation could be that researchers building ACs as assistive technology belong to another community of developers than those striving for humanoid robots.

Again, the dissimilarity of answers by the researchers is likely to reflect the differences of objectives and application scenarios of the research projects. Nevertheless we assume a shared understanding of essential properties, which a technical artefact must have in order to be labeled as a companion.

5.3 The focus of research and its ambition

The next question was about the targets and ambitions of companion research:

"The ambition of research in the field of *artificial companions* is sometimes unclear. Typically researchers treat the emotions displayed, and the internal and external state and behaviour of a computing machine with the reserve or proviso 'as if'. Notwithstanding the visionary long term claim often goes much further turning the 'as if' into real properties of the computing systems (e.g. *having* emotions).

What is your opinion about the long-term vision of artificial companions having emotions, understanding, and being conscious?"

Thirteen marked "Yes, in the long run, this vision may come true" and five marked "No, this is not a matter of time but of principle, and will never happen." Twelve respondents added comments (Table 4). The number of experts who can imagine ACs having emotions, understanding, and being conscious was higher than expected. The comments however reveal a fa-

Table 4: Selected comments on ACs having emotions...

Those holding that in the long run artificial companions may have emotions, understanding, and consciousness commented…
Both (emotions and as if) are necessary (DOMEO).
Robots mimicking emotions do not have them in an embodied way, because they are artificially added. To make advancement in this field the role of human emotions in decision making and related traits has to be understood much better, before successful implementation in artificial agents can be realized (KSERA).
If me manage to mimic our own complexity, then machines should in principle also develop something like consciousness or emotions. However, it is still questionable how long this "in the long run" may be. Nowadays, WE are the ones interpreting machines as being "alive" because they are cleverly designed and give us the key features for making this believe come true. In reality, they poorly develop something on their own, so the step towards autonomous or even conscious behaviour is still huge. Therefore, I think that "the long run" is concerning a time span including maybe even more than the next century (SEMAINE).
All these properties arise from the human brain, which is in effect a highly complex switching network, so in the very long term if we understand the biology we can build the technology (LIREC).
I have no idea what the phrase "as if" means. If it is about an artificial companion simulating emotion rather than actually having emotion, then I believe that this whole debate is somewhat misguided. It is my opinion that an autonomous system can only function effectively if it is continually appraising its current situation with regard to its own needs and goals (as well as its users' needs and goals). Such an appraisal is - by definition - a complex multidimension expression of the agent's 'feelings'. Whether such internal states are manifest externally such that they are made observable to a user is a matter of design choice. So, I answer "yes" to the question on the basis that a much more mature view of affective behaviour is required (but, in my view, possible) (COMPANIONS).
I think a robot will not really have emotions like a human (probably never), but a robot can have something that is very similar. The latest artificial neural networks already exhibit characteristics that could be labeled as emotions: e.g. surprise as the sudden rise of free energy in the artificial neural network. In addition, a robot displaying emotions (even if simulated), such as surprise, happiness, curiousness, etc can be beneficial for human robot interaction (FLORENCE).
I agree, but not completely. Actually the definitions of "having emotions", "understanding" and "being conscious" should be clearer. I can accept that robots could have high level capabilities to perceive situations and have more "feeling" with humans. Being conscious: with the advent of Internet of Things, Cloud computing/robotics and possibility to share and exploit a huge number of information, artificial companions will surely reach a very high level capability to know their environments, understanding the behaviour of people, objects and agents. Understanding: improvements in reasoning technologies will disruptively allow artificial companions to better understand their environments to make high level decisions with a sort of responsibility (responsible decision makers) (ASTROMOBILE).
I`m not sure in consciousness (SFB TRR 62).
I think it is very important that the companions provide user feedback to make its current state perceivable by the user – if this should be in human-like emotions, I am not sure (ACCOMPANY/COGNIRON).
Yes, but in a very long run, see Asimov novels. The important point is however definition, how we understand the meaning of the words emotions, understanding and being conscious. This may change with time, with societal changes. Anyway, this is an issue which will have to be treated very carefully. We need to have a companion system predictable and well defined which is in contradiction with emotions. The other thing is understanding. This may be easier accepted. Regarding the "being conscious" - first we have to understand what does it really mean. I'm afraid that this is not clear yet; however the progress towards artificial companions may help to understand and create some definition (GUARDIAN ANGELS).

cetted picture of what is really regarded feasible.[12]

The comments make apparent that the respondents operate with two different time horizons. In an abstract way some developers hold that the long term vision is principally possible, its feasibility someday cannot be excluded. This belief is not unconditional: "if we understand biology", "if we manage to mimic our own complexity, then machines should in principle also develop something like consciousness or emotions". For this vision to come true "a time span including maybe even more than the next century" may be adequate.

More to the core of the AC vision however is the idea that autonomous systems can only function effectively if they are continually appraising their current situation with regard to their own needs and goals as well as their users' needs and goals. They adapt their behaviour according to signals or feedback received from the environment, and they provide users with feedback to make their current (internal) state perceivable by their users (cf. comment by the COMPANIONS expert in Table 4). Underlying is a general cybernetic model of agency which is applied to human-beings and autonomous artefacts and to their relations. At this level of abstraction humans and machines can be described as following the same functional logic. One functional requirement is to make an internal state perceivable by others. Showing an emotion is then a typical human way to express the internal state, machines may mimic this or they may present their internal state to human users by other means. *Having* emotions is not required and may even be dysfunctional. The expert of the GUARDIAN ANGLES project commented that *having* emotions implies unpredictability; companion systems, however, should be predictable and well defined.

Next, we wanted to know, if the main purpose to develop AC technologies is an improved human-machine interface or companionship technology in its own right. The following statement was presented:

"The social properties, abilities and functionalities of (or simulated by) an artificial companion (e.g. natural language, expression of emotions, conversation strategies etc.) can be employed and interpreted in two ways: companion technology as a means to increase the user-friendliness of the human-computer-interface, or companionship as a purpose in its own right enabled by the social qualities of the artificial companion like conversation, affection, entertainment etc."

A clear majority (11 of 19) has chosen the answer that both features are always co-present in ACs and cannot be separated. Four comments explained why they have chosen the first answer (Table 5).

Three opted "companion technology is primarily about the interface-design of service robots and how to improve it" and four checked that "companion technology is primarily about enabling bonding and para-social relations with technology".[13] One expert refused to choose one of the three options. Two further comments addressed the issue (hinting at a weakness of the wording of the question) that the final purpose of technology is "to deliver some 'benefit' to users" (COMPANIONS) and that technology "is first of all a means for better quality of life of the human being. Therefore first of all it deals with the development of effective, useful and sustainable services" (ASTROMOBILE).

It is clear from the answers that companion technologies are seen in most cases as a means to an end, while a minority put emphasis on relationship building. It is however difficult to say

[12] Those who denied on principle that the far reaching vision might come true did not further explain their choice by comments.

[13] The term goes back to Horton/Wohl 1956. For a critical appraisal see Hagen 2010 and Gutmann 2011.

Table 5: Co-presence of two purposes of AC design

Those holding that that both features are always co-present in artificial companions and cannot be separated commented…
As soon as we as humans have a kind of interface which is "natural" for us, we will start to interpret our communication partner. Therefore, there is no true interaction for us without a social component (SEMAINE).
The acceptability requires the two features (ASTROMOBILE).
Isn't this obvious? (KSERA)
Companionship for a robot is a bit an overused term with a different meaning in different contexts, so it is difficult to answer this question. I think that pure companionship robots for which companionship is the only or main function will not be very popular. However, I think that many day to day robots will exploit the companionship part. In our view, robots that interact with humans in an intelligent way should act as a social actor, meaning that the user will use speech and gestures and will consider the robot to have a personality. A social robot that is present in your home should almost by definition have a personality that people like and will almost by definition be a companion and an extra guest in the home. How far this companionship goes will be strongly user-dependent (FLORENCE).

if those focusing on bonding and relationship as the main purpose have indeed pure companionship artefacts in mind or just wanted to express that their research has this specific focus.

5.4 The vision's impact on the artefact design

Following Hellige (1996) it is important that a *guiding* vision is indeed guiding and directly influencing the design of the technical systems to be developed. Therefore the experts were asked if the vision or concept of the *artificial companion* is in any way guiding or at least influencing the design (in a concrete sense) of the artefacts they build.

18 confirmed that "The concept of the *artificial companion* has certain relevance in practical terms and is influencing the design decisions", no one checked the option "is of no relevance for our work as engineers", and just one expert has chosen the answer "In our research the idea of the *artificial companion is present*, but in no way is it guiding the design (in a concrete sense) of the artefacts we build". This answer by the expert from project EXCITE is reasonable as the robot "Giraff" is not thought of as a social robot, but first of all as a communication device (see Appendix II).

Taking into account this answer and the answers regarding the crucial properties of ACs, and the AC as a specific approach to enrich the interface of assistive service robots or virtual agents, it is suggested to regard the AC vision as a vision *guiding* research – at least to a certain extent. However, we would not claim that the answers indicate more than just a rough cognitive orientation function of the term. Moreover, it is impossible to derive from the answers the degree of volition and commitment behind the "guiding vision".

Finally, we wanted to know about the relation of basic AC research and targeted AC applications. On the one hand, research and development of companion systems is today in most cases basic research with a time horizon of 10 years and more. On the other hand, as the design of human-computer relations is at the center of companion research, it is hard to imagine this type of research without involvement of potential users at an early stage. To explore this issue we asked about the required knowledge of the relevant application fields:

"Developing technology in laboratories is one thing, the deployment and dissemination of a new technology a rather different thing. How exactly and deeply do you (in your research) have to know an application field, e.g. 'elderly care', in order to build appropriate artificial companions?"

Of the 17 answers 10 confirmed that "It is impossible to build artificial companions for practical applications without deep knowledge of the application field", seven checked "We need a general idea and rough knowledge about the social settings in which the companion will be used […], but no deep knowledge […]". None of the respondents chose the third option: "We construct and build technology at a level where concise sociological and organization knowledge about the application field is not necessary". Thirteen experts added comments (Table 6).

The different comments reveal that independent of the answer chosen, there is more or less a common understanding that domain knowledge is very useful. But some regard the inclusion of knowledge from scratch as indispensable, while others tend to think that the right point in time is when it comes to demonstrators and the implementation of prototypes in real world settings. Also the comment is valid that research can be inspired by general and principle assumptions about an application field and by deep knowledge. Obviously the answers depend on whether the projects are closer to basic or applied research. The closer an AC artefact is to its application in real world contexts the

Table 6: Knowledge of users and the application field is required…

<table>
<tr><th>Those holding that deep knowledge of the application field is needed commented…</th><th>Those holding that a general idea and rough knowledge about the social settings is needed commented…</th></tr>
<tr><td>We gather real user feedback during field-trial sessions (ALIAS/1).</td><td>[…] good information about the context is necessary as there is no possibility of acquiring it autonomously (yet) (KSERA).</td></tr>
<tr><td>It is not always necessary to have that knowledge before starting a development process - it can often be gained through an intensive user and stakeholder integration process (ALIAS / 2).</td><td rowspan="2">When building demonstrators or preliminary prototypes it is more like a suggestion for society how the field of interest could be improved. Even at this stage, a concise knowledge of problems/challenges of the systems currently used is of great help. The more the developed system goes into the direction of getting really applied, the more of this knowledge is essential (SEMAINE).</td></tr>
<tr><td>If the target is not clear you cannot define the required technologies (ASTROMOBILE).</td></tr>
<tr><td>If one could make tomorrow an extremely intelligent robot with human like intelligence, there would be no need for knowledge of the application domain; the robot could learn it by itself. However, currently, it is still very difficult to find the intersection between what is currently possible with current robotic technologies and what is needed for elderly care. Deep knowledge of both domains is, in my view, a prerequisite to find these sweet spots (FLORENCE).</td><td>I am convinced that we will have a long development from specialists (systems dedicated to a very special and well defined application field, e.g. vacuum cleaners) to generalists (suitable for several application fields). For this vision, the companions need to be able to learn and to co-learn with their users with respect to environments, objects and tasks, which I don't see in the near future (ACCOMPANY/COGNIRON).</td></tr>
<tr><td rowspan="2">The deployment of an artificial companion (but also any simple device, above all in "elderly care") is guaranteed by a set of complex relationships between all stakeholders involved in it. Therefore a deep knowledge of them and more of their relationship is necessary (ASTROMOBILE /2).</td><td>We take inspirations from valid and existing biological systems to support design principles (LIREC).</td></tr>
<tr><td>Both types of knowledge are required since we research fundamental principles as well as practical applications (COMPANIONS).</td></tr>
<tr><td>It is very important to design robots from the very first beginning together with possible end-users. Otherwise an acceptance later is not guaranteed (FRIEND).</td><td>I marked the second choice above, however it is clear that more knowledge about real application scenarios is of great value (GUARDIAN ANGELS).</td></tr>
</table>

farther it will likely be from the AC vision.

6 Discussion from the point of view of TA

In this section we summarize and further interpret the findings from the empirical research and derive some suggestions for future TA studies on the subject matter. In the first of three sections we deal with the semantics behind the AC metaphor, then we turn to the technical kernel of AC artefacts, and finally we address the application level, where ACs shall be employed concentrating on ACs in elderly care as one of the most relevant application fields for which ACs are designed.

6.1 TA task one: Disentangling the AC vision

In R&D-documents of research policy and in declarations of ambitious AC-projects we found *vision statements* regarding ACs as an emerging new and challenging field of research and technical development worth time and money. In this perspective ACs are imperative: Let there be artificial companions! The research agenda is conceived as long-term endeavour requiring interdisciplinary cooperation. This is confirmed by the experts' comments. The increasing literature and the concrete AC-projects have shown that the R&D-vision has started to move from words to deeds.

However, to be precise, the vision by and large is not (yet) attached to a specific term. The "artificial companion" is just one term in a semantic field of related terms such as "social robots", "relational agents", or "sentient machines". The observation that the vision is not attached to one single term has also been proven by the answers of the experts when asked which terms they would regard as proper descriptions of their research field.

There is not yet a clear hierarchy of terms in this semantic field. For example, on the one hand an AC can be perceived as a sub-category of a social robot, on the other hand it can also be used as an umbrella term covering for example physical robots and virtual agents (softbots) or service robots and social robots. It remains to be seen if the label AC will prevail over other labels and approaches in the years to come.

Notwithstanding, for the time being, the companion metaphor by itself is a particularly interesting one, because unfolding its meaning various properties come to the fore which allow to encompass a whole range of rather different objects as artificial companions.

The term "artificial companion" is obviously exploiting the semantics of companion and companionship. In a wider sense, many things which accompany a person or which are *present long-term* in his or her personal environment and which are at the same time *somehow useful* might be termed companions: from favorite self-help books (like "The New Food Lover's Companion" or the "Clinical Companion to Medical-Surgical Nursing" or the "Vade-Mecum of the Oboist" etc.) to books people are used to carry with them like e.g. the bible or favourite poetry, and further on to PDAs (personal digital assistants) and smartphones (cf. answer of ALIAS, Table 2; see also Sugiyama/Vincent 2013). In this understanding also an intelligent wheelchair (FRIEND) can be called a companion or friend.

One step further on, ACs – embodied as robotic or virtual agents and provided with properties such as autonomy, interactivity, adaptivity – are designed to deliver some sort of useful service for individual human beings. Looking at European research projects we were able to distinguish monitoring & assistance services from services requiring some sort of partnering and bi-directional exchange. Often the prototypes under development aim to combine features of the different types of services.

In cases where the service to be provided by an AC focuses on assistance the advanced HCI (natural language, gestures, showing cues of emotions etc.) is a means to an end: ease of use. And this is still compliant with the tool or machine metaphor. If multi-modal interfaces encourage long term-use and provide for acquaintance, familiarity and emotional bonding with the artefact, which then again increases the ease of use, we are still thinking within the frame of assistive technology. Robots bringing water, opening doors, or mediating telecommunication are examples of this service type.

When the interaction with the artefact becomes an end in itself, we glide over to another class of services. There is a whole range of applications in which the AC is designed as interaction partner for specific purposes in areas such as learning, training, therapies or playing. These services also cover the case in which the human has to take care of the robot – discussed by Dautenhahn (2007: 698-700) as "caretaker paradigm" in human-robot-relationships. Objects deserving attention and engagement (needy machines) are a case in point. The "Tamagochi" comes to mind as an instance of this paradigm aimed at entertainment and learning (social skills) by playing. In the European research context this sub-type is also present (see the projects we classified as "Companions as Partners"), but according to our survey the AC as assistant appears to be prevailing.

The very idea of *companionship as a service* goes beyond defined and determined specific functions of ACs. This becomes evident e.g. in an introduction to the COMPANIONS project. It starts considering that a "loss of human companions is a natural consequence of growing old" and concludes: "With consideration of this natural decline in human companionship, the potential value of developing artificial companionship becomes distinctly apparent" (Benyon/Mival 2007:193). Recently ACs have been proposed as companions during long-lasting space missions (Berger et al. 2012). In both cases the assumption is that a lack of human companions and the need of human companionship can be compensated by ACs.

Companionship as a service is no longer tied to one single useful service to be performed. It indicates a generalized functionality: to be present when needed and to support the other in many ways when required. At this level of abstraction the artificial companion compares in ambition to the General Problem Solver of the early days of AI research (Böhle et al. 2011: 137).

At this crossroad, well defined strands of research and development of service robots run the risk of turning into non-scientific, speculative socio-technical imaginaries, i.e. science fiction within science. The companion metaphor invites to be extended and stretched to a far reaching techno-futuristic vision, in which the AC is loaded with more and more properties once defining human beings as companions of other human beings (see the definition of Dautenhahn 2007: 686 quoted above). Visionary thinking can imagine more and more "personality", "sociality" and "lifelikeness" of machines. This kind of thinking is not new within the discourse of AI and present in transhumanist thinking (cf. Coenen 2009). It can be exploited to bolster the companion metaphor. These techno-futuristic visions may be of little use as guiding visions for actual research and may be taken seriously by just a few researchers in the field, but they may attract attention and debate when they enter the public sphere. Even among the experts surveyed some could imagine artificial companions of that type at the end of a long term development over several decades.

In most cases the envisaged use case even for these farfetched artificial companions is still the delivery of services and the term companion is still used metaphorically. Among human beings companionship usually presumes consent between the companion and the accompanied as well as reciprocal acknowledgement, and it is further presumed that a companion has the choice not to follow and not to be present, and to ignore demands and expectations of the other. This also holds for companion animals to a certain degree. The disobeying robot companion not willing to stick to the functionality it was designed and programmed for would be an undesired accident, and is therefore a popular topic nurturing science-fiction at least since the old days of the industrial revolution.

To sum up, the companion metaphor covers a broad spectrum of potentially useful artefacts – from simple objects to imagined highly complex life-like objects – delivering services for personal use. In this generality, the companion metaphor may also serve as an expression indicating that in the "next society" various types of intelligent artefacts will accompany us providing services and be part of our everyday life (cf. Baecker 2011). More specifically artificial companions are designed as computer artefacts delivering new *personalized* services in everyday environments. As the survey has revealed most researchers see themselves as developers of assistive technologies and not of humanoid robots. This suggests the hypothesis that the service orientation is most relevant for European AC researchers.

The AC as umbrella term is likely to render "organizational qualities" (Rip/Voß 2013: 40) delineating a new interdisciplinary research field to which different scientific communities shall contribute. In particular two communities are invited to join forces and to cooperate: HCI-developers of multi-modal interfaces interested in the ease of use of services and those developing new interactive services, in which the interaction with the computer (as partner) is the service and therefore an end in itself.

The companion metaphor can be misleading in three ways: firstly, it is suggesting to take into account only the bi-directional exchange between user and artefact, while in practice the technical artefact will often mediate and serve purposes defined by third parties (educators, physicians, relatives etc.) – and users will be aware (more or less) of this triadic constellation.[14] Secondly, the attribution of a human being as a companion has to be thought of as an integral and holistic capacity and disposition, integrating a multitude of services. Artificial companions to the contrary are in practice delivering only one or a few rather specialized services. Thirdly, it would be further mistaken to think that AC research is aiming to implement essential conditions of human companionship, while in practice its focus is on the substitution of selected services, delivered previously mainly by paid professionals. Well defined functions once performed by human beings have already long since been replaced by interactive computer systems. The ATM, the automatic teller machine, is a well-known case in point. The envisaged ACs are different as they aim at providing specific *personalised* services in everyday environments. More precisely: specific service functions performed by humans acting as *personae* in determined professional roles – like butler, nanny, servant or nurse –, are to be replaced by ACs.

Table 7 represents the three levels of the AC metaphor in a schematic way

[14] At least social sciences should be aware of the basic "triadic" setting when analysing human-robot-interactions (Höflich 2013). See also Pfadenhauer in this issue.

adding a few hints at relevant application fields.

The semantic analysis of the AC and the companion metaphor based on empirical research has led us to detect the entry point for TA: new types of computerized services to be developed and to be put into practice by possibly long-term innovation processes. Researchers were thinking of a research agenda taking decades. Nevertheless, even today there are many prototypes available, which can be analysed. In this respect ACs are a kind of new and emerging technology with a long term horizon on the one hand and an incipient innovation process which can already be investigated on the other hand. The speculative extensions of the AC vision are therefore less interesting for TA than the early stages of the innovation processes and the incipient penetration of application fields with ACs. In a reflexive loop TA would also have to tackle the policy relevant question whether the research on ACs and social robots is a meaningful endeavor at all and assess the objections against this new, quickly growing strand of interdisciplinary research (see Weber in this issue).

6.2 TA task two: Assessing the state of the art of AC technologies

A general task of TA is to assess the state of technological developments. This exercise is also necessary to come to terms with the different time horizons (short-term and long-term) with respect to AC developments. It is important to discern basic research from applied research where prototypes and products are already tested and used in concrete application fields.

Taking into account previous research (Böhle et al. 2012), the literature, and comments by the experts surveyed we would hold that the technical kernel and the organizing principle of ACs is about the adaptivity of the machine in combination with a multi-modal interface. One way to increase the adaptivity of companion systems is to dynamically feed the computer application with data about an individual person and its environment. ACs can only function effectively if they are continually appraising their current situation with regard to their own "needs" and "goals" as well as their users' needs and goals. They adapt their behaviour according to signals or feedback received from the environment, and they provide users with

Table 7: Aspects of the companion metaphor

metaphorical level	service level	application field
companion metaphor in a general sense	helpful, reliable, easy to use, long-term use and presence in everyday life	everyday life (reference books, PDAs, smartphones, gadgets…)
		health care (intelligent wheelchair, wearables, further AAL technologies…)
companion metaphor for robotic and virtual agents	a) personalized assistive services in general... (HCI as a means to an end)	health, elderly care, military companions …
	b) personalized interactive services, in which the interaction with the computer is the service (HCI as an end in itself); computerisation of specific service functions	health care, therapies, elderly care, education, toys, computer games…
companion metaphor in techno-futuristic discourse	replacing humans as servants & friends (general purpose substitutes with human-like qualities)	health care by humanoid robots, robots as sex partners, avatars representing a deceased person (digital immortality) …

feedback to make their current (internal) state perceivable by their users (cf. comment in Table 4 by the COMPANIONS expert, see also for an overview Sheridan 2011, Broadbent et al. 2009, Sharkey and Sharkey 2012). Underlying is a general cybernetic model of agency.[15]

The enquiry of the state of the art and further a reality check is a duty of TA.[16] It is an antidote to speculative visionary thinking and as such contributing to the STF-D about new (hyped) technologies. In the case of companion technologies this means to scrutinize the claimed properties and capacities of ACs in order to separate hype and promises from realistic expectations. A TA study of ACs would have to evaluate the state of the multi-modal interface and its components, autonomy, interactivity, adaptivity and related properties such as learning.[17] With respect to the conversational abilities of ACs, Lücking/Mehler have already proposed (in this issue) a useful evaluation and assessment schema.

At this point the understanding of TA as interdisciplinary and participatory research means to involve technical experts and designers of ACs. Some of them do already evaluate and compare different systems within the engineering disciplines. Interchange with them is indispensable for the assessment of the state of the art and the feasibility of envisaged artefacts. This task of TA is becoming policy relevant as soon as it takes the form of a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) comparing relevant national or European research with the one of other countries or world regions.

6.3 TA task three: Contributing to the STF-Discourse about ACs in relevant application fields – the case of elderly care

The task of TA changes as soon as we leave the R&D level and turn to specific application fields where the new technology is meant for. Many AC researchers are of the opinion that healthcare and elderly care will be an important application area of future robot systems and thus for companion systems too (Böhle et al. 2011: 142).[18]

Breazeal even uses the word killer application in this context:

> "Possible indispensable applications, a.k.a *killer apps*, for social robots could be in health-related domains including eldercare, therapeutic interventions for children with autism, behavior change coaches in areas such as chronic disease management, health education, patient advocacy, or as a new kind of tele-medicine interface" (Breazeal 2011: 5368).

Other imaginable application fields for ACs are e.g. military applications, work environments, games, education (cf. also Leite et al. 2013), but health care seems to be dominant. Also in the public debate the link between demographic change and elderly care as problem, and ACs as a potential solution is prominent (cf. Becker et al. 2013).

In the current debate on the aging society a "clash of the increasing needs

[15] For further information explaining this approach see Russel/Norvig 1995, Luck et al. 2005, and Sheridan 2011.

[16] In a recent study on pharmacological enhancement, to give but one example for the need of this type of reality check, it could be proven that "there exist at present no pharmacological substances that have been shown to bring about a relevant enhancement of cognitive performance in healthy individuals" (Sauter and Gerlinger 2013: 211).

[17] Floridi and Sanders regard the criteria of interactivity, autonomy, and adaptability as decisive for the characterisation of artificial agents (2004: 357-358).

[18] As an aside, the question comes up, why healthcare is apparently the most visible and promoted application field targeted by public companion research? Could it be that "good for health" is simply an irresistible door opener to raise funds? Could it be that basic research is more and more forced to articulate at an early stage its utility – with "good for health" as the default answer?

for formal care with the decreasing availability of labor" is often assumed (cf. Rothgang et al. 2012: 105-107). Engineers and R&D managers are aware of this anticipated supply gap and may therefore promote their technologies as part of the solution, and ACs as a piece thereof. In 27 out of 39 European companion projects the main targeted application field was indeed health and elderly care.

Because of the public debate and the political dimension of the transformations of the care sector, the investigation of ACs in this context is of high political relevance and therefore a case for TA. From a TA perspective the main issue is the change of the healthcare sector as a socio-technical constellation (including e.g. new care arrangements). TA would have to address the question of technology push and demand pull in this sector and the question how technical and social innovations are entangled.[19] This approach could be further extended to eventually come up with a description of the relevant socio-technical constellation and its dynamics. It is for instance not yet clear if there exists at all a sufficiently powerful innovation network pushing the implementation of ACs in the healthcare sector.

It is interesting to see that vision assessment reappears as an exercise within TA at this level. We can observe the entry of the AC as R&D vision and its transformation within the wider STF-D. The imaginaries of the R&D sector are confronted with the public debate and imaginaries stemming from the application field. To give but two examples, Yumakulov et al. (2012) have shown for instance – analysing technical AC literature – that the imaginations of engineers envisaging the need of ACs and modelling their users are at odds with the self-perception of handicapped persons and don't match their needs for assistive technologies.

The second example starts from the observation of competing guiding visions in the healthcare sector. It could well be that for instance the socio-technical imaginary of Ambient Assisted Living (AAL) is so dominant and comprehensive in this sector that there is no place left for the AC vision as a single topic of debate. From the AAL point of view, the AC (as a term) might disappear being perceived as many different types of technical support devices and programs.

As stated before, TA means interdisciplinary and participatory research. If the change of the healthcare sector as a socio-technical constellation is the subject matter, many stakeholders concerned with care, researchers, practitioners, persons in need of care, and other affected persons would have to be included in the participatory analysis. In the best of cases TA would be able to reflect the relevant STF-D and to contribute to it.

[19] See Meyer 2011, Krings et al. 2013 and Becker et al. 2013 for the current discussion on the role of technology and especially ACs in healthcare and elderly care.

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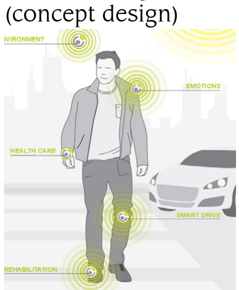
Appendix I: List of experts

Project Acronym	Name	Function
ACCOMPANY/COGNIRON	Ulrich Reiser	Consortium
ALIAS-1	Frank Wallhoff	Coordinator
ALIAS-2	Not for public	Consortium
ASTROMOBILE-1	Franz Stieger	Consortium
ASTROMOBILE-2	Filippo Cavallo	Coordinator
COMPANIONS/SERA-1	Roger K. Moore	Consortium
COMPANIONABLE-2	Not for public	Consortium
COMPANIONABLE-3/ALIAS-3	Not for public	Consortium
DOMEO-1	Vincent Dupourque	Coordinator
EXCITE	Silvia Coradeschi	Coordinator
FLORENCE/ COMPANIONABLE-1	Dietwig Lowet	Coordinator/ Consortium
FRIEND	Torsten Heyer	Coordinator
GUARDIAN ANGELS	Piotr Grabiec	Consortium
HOBBIT/DOMEO-2/KSERA	Wolfgang Zagler	Consortium
KSERA	Raymond Cuijpers	Coordinator
LIREC	Peter McOwan	Coordinator
SEMAINE	Sirko Straube	Coordinator
SERA-2	Not for public	Consortium
SFB TRR 62	Steffen Walter	Consortium

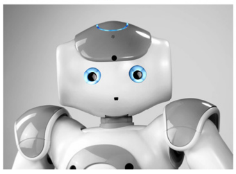
Appendix II: Short description of the 17 companion projects selected

The following table gives an overview of the selected European companion projects. It contains a short description of project objectives and envisaged application scenarios. Further the companion systems are presented in detail with regard to its *monitoring*, *assistance* and *companionship* features. In addition small pictures illustrate the artefacts.

Name/ Duration/ Funding / Project lead	Aims of Research	Artificial Companion	Functionalities/ Capabilities
GUARDIANS			
GUARDIAN ANGELS - for a smarter life (FET Flagship Pilot) May 2011 - May 2012; 1.7 million Euro	Providing information and communication Technologies to assist people in all sorts of complex situations is the long term goal of the Flagship Initiative Guardian Angels (GA).	**Guardian Angels** (concept design) 	**Monitoring** monitor the physical/ physiological status of individuals with an awareness of the context of activity, emotional conditions and environmental context

ASSISTANTS			
FRIEND - Functional Robot with dexterous arm and user-frIENdly interface for disabled people ReIntegraRob: Apr 2010 - Apr 2013; 0.41 million Euro (Ministry of Integration Bremen)	The care-providing robotic system is designed to support disabled and elderly people in their daily life activities, like preparing and serving a meal, or reintegration in professional life.	**Friend III** (IAT, University of Bremen) 	**Assistance** moving in the wheelchair; taking and carrying things with the robotic arm (cook a meal)
ACCOMPANY - ACceptable robotics COMPanions for AgeiNg Years Oct 2011 - Sep 2014; 3.6 million Euro (FP7, e-inclusion)	The proposed system will consist of a robotic companion as part of an intelligent environment, providing services to elderly users in a motivating and socially acceptable manner to facilitate independent living at home.	**Care-O-Bot 3** (Fraunhofer IPA) 	**Monitoring** monitoring vital signs; emergency alarm **Assistance** agenda management; drinking and medication reminding; telepresence services; detect and grasp objects and pass them safely to human users (e.g. drinks) **Companionship** playing songs and games
DOMEO - domestic robot for elderly assistance July 2009 - July 2011; 2,4 million Euro (FP7, AALJP)	DOMEO focuses on the development of an open robotic platform for the integration and adaptation of personalized homecare services, as well as cognitive and physical assistance. 	**robuMATE, robuWALKER** (Robosoft) 	**Monitoring** emergency alarm (robuMATE); monitoring the heart rate (robuWALKER) **Assistance** telepresence services; spoken messages; medication, meal, drinking reminding; create a shopping list; stimulation for doing physical exercises (robuMATE); stand-up and walk assistance (robuWALKER) **Companionship** speech output, providing games (robuMATE)
COMPANION-ABLE - Integrated Cognitive Assistive & Domotic Companion Robotic Systems for Ability & Security Jan 2008 - June 2012; 7.8 million Euro (FP7, e-inclusion)	CompanionAble addresses the issues of social inclusion and homecare of persons suffering from chronic cognitive disabilities prevalent among the increasing European older population.	**Hector** (SCITOS G3, MetraLabs) + smart home system 	**Monitoring** monitoring vital signs; emergency alarm; homecare monitoring (e.g. freezer, cooker) (smart home system) **Assistance** agenda management; cognitive training; drinking and medication reminding; telepresence services; store small things in its back **Companionship** playing simple quiz games; animated eyes

ALIAS - The Adaptable Ambient Living Assistant July 2010 - July 2013; 4 million Euro (AALJP, FP7)	A mobile robot system that interacts with elderly users (living alone at home or in care facilities), monitors and provides cognitive assistance in daily life, and promotes social inclusion by creating connections to people and events in the wider world.	**Alias** (Scitos A5, MetraLabs) 	**Monitoring** health monitoring **Assistance** telepresence and online services **Companionship** speech output; providing games; mechanical eyes
ASTROMOBILE - Assistive SmarT RObotic platform for indoor environments: MOBILity and intEraction July 2010 - Dec 2011; (ECHORD project FP7)	The project is focused on the development and deployment of a smart robotic assistive platform, with particular attention to the problem of navigation and interaction to improve services, such as communication, reminder functions, monitoring and safety, useful to the well-being of humans or equipments.	**Astro** (SCITOS G5 MetraLabs) + smart sensor network 	**Monitoring** environment alerts (e.g. door, faucet, gas) (smart sensor network) **Assistance** stand-up and walk assistance; telepresence services; medication, appointment reminding
FLORENCE - Multi Purpose Mobile Robot for Ambient Assisted Living Feb 2010 - Feb 2013; 5.3 million Euro (FP7, e-inclusion)	Florence will keep elderly independent much longer by providing care and coaching services, supported by robots. This will greatly improve the efficiency in care and reduce costs. The second problem addressed by Florence is the acceptance of robots by elderly.	**Florence robot** (Philips) + smart home system 	**Monitoring** monitoring weight and physical activity; fall handling service; emergency call **Assistance** telepresence services; home interface service (DoorGuard, Energy Saving) **Companionship** speech output, providing collaborative gaming, animated smiley face
EXCITE - Enabling Social Interaction through Embodiment July 2010 - Jan 2013; 2.8 million Euro (AALJP, FP7)	The project will achieve a breakthrough in the application of telerobotics to elderly care by developing a low-cost, easy-to-use device with practical functionality.	**Giraff** (Giraff Technologies AB) 	**Assistance** telepresence services (only remote controlled)

KSERA - Knowledgeable Service Robots for Aging Feb 2010 - Jan 2013; 3.9 million Euro (FP7, e-inclusion)	The project will research and develop a Knowledgeable Service Robot for Aging that will serve several related purposes for elderly persons in general and those with pulmonary disease in particular.	**Nao** (Aldebaran) + smart household technology 	**Monitoring** monitoring vital signs; emergency alarm; direct measurements and interaction with wearable and household sensors to detect normal and anomalous daily living patterns **Assistance** provide useful information; support disease self management **Companionship** affective communication; adaptive non-linguistic and linguistic behaviour
SERA - Social Engagement with Robots and Agents Jan 2009 - Jan 2011; 1.5 million Euro (FP7)	The project aims to advance science in the field of social acceptability of verbally interactive robots and agents, with a view to their applications especially in assistive technologies.	**Nabaztag** (Violet) + room equipped with sensors 	**Monitoring** monitoring daily exercises **Assistance** web based services; health- and fitness-related assistance **Companionship** ear movement; changing body colours
COGNIRON - the Cognitive Robot Companion Jan 2004 - Feb 2008; 8.4 million Euro (FP6; SFB 360)	The overall objectives of this project are to study the perceptual, representational, reasoning and learning capabilities of embodied robots in human centred environments.	**Cognitive Robot Companion** (concept design) 	**Assistance** serve humans as assistants or companions, cognitive capacities for adapting its behaviour to be able to respond to the humans' needs
Partners			
COMPANIONS - Intelligent, persistent, personalised multimodal interfaces to the internet Nov 2006 - Nov 2010; 12.5 million Euro (FP6)	The project has developed virtual companions for conversation to change the way people think about the relationships of people to computers and the Internet.	**Samuela** (Companions-Project) 	**Companionship** communication partner; affective conversational system, which establishes a relationship with the user and supports the user emotionally
SEMAINE - the sensitive agent project Jan 2008 - Jan 2011; 3.6 million Euro (FP7)	The aim of the project is to draw together the current research on non-verbal signs and to produce a system that capitalises on them to achieve genuinely sustained, emotionally coloured interactions between a person and a machine.	**SAL** - Sensitive Artificial Listener (Semaine) 	**Companionship** affective conversation, react appropriately to the user's non-verbal behaviour

LIREC - Living with Robots and Interactive Companions Jan 2008 - Aug 2012; 10.9 million Euro (FP7)	LIREC is a research project exploring how we live with digital and interactive companions. Throughout the project we're exploring how to design digital and interactive companions who can develop and read emotions and act cross-platform. Games provide an ideal context for exploring some of these questions.	**Pleo** (Innvo Labs), **iCat** (Philips), **EMYS head** (Wroclaw UT)  	**Companionship** artificial playmates; communicating in verbal and non-verbal ways 
HOBBIT - The Mutual Care Robot Nov 2011 - Nov 2014; 2.8 million Euro (FP7)	The new focus of HOBBIT is the development of the mutual care concept: building a relationship between the human and the robot in which both take care for each other. In addition, the robot will provide other support such as opening the door for the user and learning the needs and habits of its owner.	**Hobbit** (concept design) 	**Companionship** Possibility for the human to "take care" of the robot like a partner, real feelings and affections toward it will be created (mutual care concept)
Others			
SFB TRANSREGIO 62 - A Companion-Technology for Cognitive Technical Systems since 2009; (DFG)	**Companionship** Possibility for the human to "take care" of the robot like a partner, real feelings and affections toward it will be created (mutual care concept)	Basic research, no ACs yet	not specified

Apendix III: Webpages of selected projects [last visit 2013-10-15]

Accompany: <http://accompanyproject.eu/>
Alias: <http://www.aal-alias.eu/frontpage>
Astromobile: <http://www.echord.info/wikis/website/astromobile>
Cogniron: <http://www.cogniron.org/final/Home.php>
Companionable: <http://companionable.net/>
Companions: <http://www.companions-project.org/>
Domeo: <http://www.aal-domeo.eu>
Excite: <http://www.oru.se/excite>
Florence: <http://www.florence-project.eu/>
Friend: <http://www.iat.uni-bremen.de/sixcms/detail.php?id=1090>
Guardian Angels: <http://www.ga-project.eu/>
Hobbit: <http://hobbit-project.eu/>
Ksera: <http://www.ksera-project.eu/>
Lirec: <http://lirec.eu>
Semaine: <http://www.semaine-project.eu/>
Sera: <http://project-sera.eu/>
SFB Transregio 62: <http://www.sfb-trr-62.de/>