# Towards a Methodology for Longitudinal Evaluation of Social Robotic Telepresence for Elderly

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## ABSTRACT

This paper describes a methodology for performing longitudinal evaluations when a social robotic telepresence system is deployed in realistic environments. This work is the core of an Ambient Assisted Living Project called ExCITE, Enabling Social Interaction Through Telepresence. The ExCITE project is geared towards an elderly audience and has as aim to increase social interaction among elderly, their family and healthcare services by using robotic telepresence. The robotic system used in the project is called the Giraff robot and over a three year period, prototypes of this platform are deployed at a number of test-sites in different European countries where user feedback is collected and fed back into the refinement of the prototype. In this paper, we discuss the methodology of ExCITE in particular relation to other methodologies for longitudinal evaluation. The paper also provides a discussion of the possible pitfalls and risks in performing longitudinal studies of this nature particularly as they relate to social robotic telepresence technologies.

## Keywords

human-robot interaction, robotic telepresence, long-term evaluation, user-evaluation methodology

## 1. INTRODUCTION

Telepresence has long been advocated as a means to enable virtual face-to-face communications for people located at different places. A newer variant of telepresence has recently emerged which proposes to integrate ICT technologies onto robotic platforms and to enable actuation in a remote location. So far robotic telepresence has made a debut in the deployment of robotic systems in dangerous or unreachable environments. However, a number of systems are starting to emerge that advocate the use of robotic telepresence in a domestic or office environment. The use of such systems as a tool to enhance social interaction to cope with the aging society issue is still relatively novel. However, used as a device to increase social interaction, robotic telepresence could be particularly suited to an elderly audience for a number of reasons. Firstly, the elderly interacts with the robot in a natural and intuitive manner as little additional learning is required for the elderly. Secondly, the client connecting to the robot from a remote location gains a greater level of control which is currently not possible in desktop type telecommunication applications. In particular, this greater level of control allows the client to move in the environment. Thirdly, this particular type of technology is suitable for a diverse group of elderly including those who are very mobile (with multiple residences) who want to maintain contact with their family kin etc.; as well as those who are less mobile and want to connect to the device to gain a greater sense of mobility and access. Fourthly, the social robotic telepresence system could increase the sense of safety as well as decrease the sense of loneliness for the keeper of the robot. Despite this potential, the number of existing systems which advocate better social interaction have indeed only been subject to either little or no end-user validation with an elderly audience.

The aim of the ExCITE[1] project is to leverage upon a close to market robotic telepresence solution called the Giraff robot and develop this platform so as to meet the needs of users in the context of providing new tools for facilitating better

[1]The ExCITE consortium consists of Örebro University, Giraff Technologies AB, Consiglio Nazionale delle Richerche (ISTC-CNR), Ratio Consulta, University of Malaga and Örebro City Council. The project's webpage is http://www.excite-project.eu.

care for the elderly. In this sense users consist not only of the elderly but also of the formal and informal caregivers. Platform development is done by taking into account the outcomes from the user evaluations which is done by deploying the robot in realistic environments and homes called test-sites. Each test-site is to use the Giraff over a longer period of time and hence the longitudinal aspects of technology deployment are also implicitly considered. The ExCITE standpoint lies in its pragmatic approach which employs a relatively simple but robust technology. While this technology may offer only limited but consolidated functionalities, the project aims to primarily investigate the challenges that may arise from a deployment in real contexts. This pragmatic approach can then provide useful suggestions and guidelines to further improve the robotic features as well as to realize what automatic functions that correspond to user's needs.

In this paper we outline connected research issues in Section 2. The user-centered methodology used within the ExCITE project is described in Section 3. In Section 4, we discuss the methodology and possible pitfalls and risks when performing longitudinal studies in real environments.

## 2. RELATED WORKS

Telepresence and mobile telepresence concepts have been envisioned, built and even commercialized since the 1980s. Telepresence provides for virtual face-to-face communications for people located at different places. However, it limits its visual communications to pre-established views and does not allow users the "walking around" experience. Mobile telepresence or "telerobotics" - the combination of teleoperation and telepresence offers this additional "walking around" capability and is the key contribution that the Giraff concept achieves for home care. An example of fixed-location telepresence for home care is the ACTION platform, an EU-project that designed a video conferencing responsive support service for caregivers of elderly people. This project was driven by University College of Borås and is now deployed in the city of Västerås, Sweden. The product has achieved some commercial success but has been held back by its lack of mobility. Telerobotics include concepts such as Robonaut (an extravehicular activity astronaut equivalent), Robovolc (designed to perform autonomous and/or semi-autonomous exploration and perform measurements in a volcanic environment). A new generation of telerobotics specifically for social interaction include Giraff (Giraff Technologies), QB (Anybot), Texai (Willow Garage) and Vgo (Vgo Communications) which provide suitable platform for a multitude of users.

While the use of robotics in eldercare is not novel, most robotics concepts have been born of academic or other research-oriented projects, and focus primarily on autonomy, artificial intelligence and the ability to perform physical tasks [14], [13], [4]. While these capabilities advance the state-of-the-art in the field they are usually not practical or reliable enough for commercial deployment. Further, as many devices have not advanced beyond the prototype stage, they require a great deal of technical support and interaction. Sophisticated autonomous devices that require near-constant attention by the designers may advance knowledge in the field but are not suitable for real-world deployment. As a result, very little real user experience has been gathered, processed and fed back into these design concept and the nature of the physical platform makes in unfeasible to do so. So while there is currently a push towards ICT solutions for an elderly demographic specifically where those solutions are backed by real user experiences, there is also a need to develop methodologies for eliciting user requirements in real contexts. So far, most HRI evaluations have been done on short-term basis and in many cases in laboratory settings. While these evaluations give information about various factors that can affect user acceptance or persistence one can not omit that insecurity or a novelty effect might influence the users' behaviors and reactions in the interaction.The novelty effect does seem to have effect on use of systems as can be seen in Heerink etal [6] where it is reported from a long term evaluation at eldercare institutions with the iCat that the more people perceive a robotic system to be enjoyable, the more they intend to use it. And the more people intend to use a robotic system, the more they will actually use it. On the other hand, e.g. preferred distance to robots seem to change over time. Pacchierorotti etal [12] reports from a study in which proximity was investigated with 10 subjects in a narrow corridor setting. It was found that people felt less comfortable when the robot entered their intimate sphere (<45 cm) and that normal avoidance behavior was preferred, i.e. large maneuvers to avoidance were regarded as uncomfortable and unnatural. Two papers conducted within COGNIRON also reports about personal spatial distance [9, 20]. While [20] was done as a short-term evaluation in which it was found that the majority preferred an approach distance for robots compatible with the one for normal social interaction with other humans [9] reports that preferences changed over time as the users habituated to a social robot over a period of five weeks. The participants allowed the robot to come closer after habituation. On the first interaction there was a difference in allowed distance depending on approaching direction, this was not existent in the end of the experiment. This indicates that the novelty effect makes people feel insecure when first exposed to robots.

Evaluations within work settings were done in a long-term perspective are [11, 17]. Mutlu and Forlizzi [11] report that organizational factors affect the way its members respond to robots and the changes engendered by their use in a 15 months study. This shows that for products to be evaluated properly they must be evaluated with their intended users in real settings as the response from users are dependent on their use and of what they are replacing. Severinson etal [17] reports from a 3-month field study with the service robot Cero with a single user in a workgroup setting. The long-term study brought up more than 100 different design issues. While short-time studies certainly might have brought up some of the design issues this in itself motivates the need to perform long-term evaluations outside lab premises.

## 3. THE EXCITE PROJECT

The motivation of ExCITE is to progress the development of technology to facilitate social interaction of people potentially isolated in order to increase their social participation, decrease their sense of loneliness and contribute to better health. The approach of using ICT technologies for enhanced social interaction is not a new concept, however the

combination of video conferencing technolgies with robotics for an elderly end-user is novel. The methodology is highly inspired a user-centric approach used to prototyping, validating and refining solution in both multiple and evolving real contexts. Such validations occur in a cyclic fashion where the prototype is deployed in a number of end-user sites, qualitative and quantitative data of user feedback is obtained, changes to the prototype and the necessary infrastructure are accounted for, and the prototype is re-deployed. For this methodology to be successfully applied, this project proposes a strategy which involves the end users and researchers in a tightly knit collaboration. By grouping the researchers and the end users in the nucleus, the connection between innovation and research is reinforced by creating a direct correspondence between user needs and research goals. The aim is to achieve a refined prototype that would be more readily exploitable by the industry as a base for creating a commercial product. Ideally, this product will be highly effective in promoting a healthy aging and social well being as it has been previously validated. Further, the wealth of data obtained through the evaluation will provide important research challenges as these challenges will emerge directly from real contexts. In this section we outline the basic building blocks of the ExCITE project which include the physical platform, the user centric methdology and a description of a first test-site.

## 3.1 The Giraff Telepresence Robot

The Giraff provides a means for achieving remote communication between two parties. On one end, there is a mobile robotic base equipped with a web camera, a microphone and a screen. Specifically, the camera and screen are mounted on a tilt unit. A user interacts through the robotic device with a peer who connects through a client interface. The client interface on the other end allows the user to teleoperate the Giraff while speaking through a microphone and a web camera and receiving the video and audio stream from the Giraff. Graphical depictions of the robotic device are given in Fig. 1 (a) and (b)

Currently, the local user can only receive calls but may decide whether he/she wants to accept the call or reject it by clicking on one of two buttons on a remote control. In turn, The client interface is designed to be intuitive and easy to learn and allows the client-user to tilt the Giraff screen up and down as well as to navigate around in the home of the elderly while interacting. Navigation is done by pointing directly on the real time video image and pushing the left button on the mouse. A snapshot of the client interface is shown in Fig. 1 (c). More details on the technical specifications of the platform can be obtained by the manufacturers webpage: www.giraff.org.

## 3.2 User Centered Evaluation

Evaluating e.g. social robotic telepresence systems such as the Giraff particularly with an elderly focus require consideration of feedback from a variety of potential yet different users. Therefore, the methodology is highly inspired by a user-centric approach to prototyping, validating and solution refinemen where users encompass not only the elderly person but also the different types of care givers. It can be expected that the future Giraff, or other social robotic telepresence systems, will be deployed in various environments and that it will be used in different forms of interaction. Deployment of robots in real settings with elderly users with different technological ICT-knowledge may potentially pose different problems in use of the technology as well as interaction. Therefore, it is our aim to evaluate the system in different forms of interaction as described in Table 1.

**Table 1: Configurations for which evaluations are to occur within ExCITE.**
**Y = Yes, N = No**

| Client-User / End User | Healthcare professional | Family member | Elderly user |
|---|---|---|---|
| Healthcare professional | N | N | Y |
| Family member | N | N | Y |
| Elderly user | N | Y | Y |

The platform is evaluated according to a set of parameters that include functionality, usability, privacy and acceptance and are further described below.

## 3.3 Functionality

Any assistive technology must perform correctly to serve the purpose of facilitating independent living. For instance, consider the use of a tool for remote health monitoring or fall detection. The capability of the tool to measure falls must be sufficiently accurate for sending an alarm when necessary, but it must also ensure that the occurrence of false positives is as limited as possible. It must also be robust enough to stay connected for a long period of time to be reliable for the health personnel. In our particular study it is important to ascertain the reliability and robustness of the Giraff platform. This includes measuring the frequency and contingencies under which software failures occur, as well as the particular aspects related to the stability of the network connection over which communication

occurs.

## 3.4 Usability

Assistive technologies are meant to assist the people using them rather than creating new challenges. Users, who are often the elderly people themselves, cannot be expected to be familiar with ICTs and may also have mental or physical problems. The assistive technology must be easy and intuitive to use. As pointed out in [10], attributes that are meaningful for assessing usability include Ease of Use, Accessibility and Non-Obtrusiveness.

### *3.4.1 Ease of Use*

Assistive technology needs to be easy to use both by the end-user and by the people in charge of setting it up. This entails an evaluation of the user interface as well as the interfaces dedicated to system setup and maintenance [10]. The Giraff platform has strong similarities with existing network communication tools such as Skype. Indeed, the teleoperation interface of the Giraff is similar to a Skype video interface

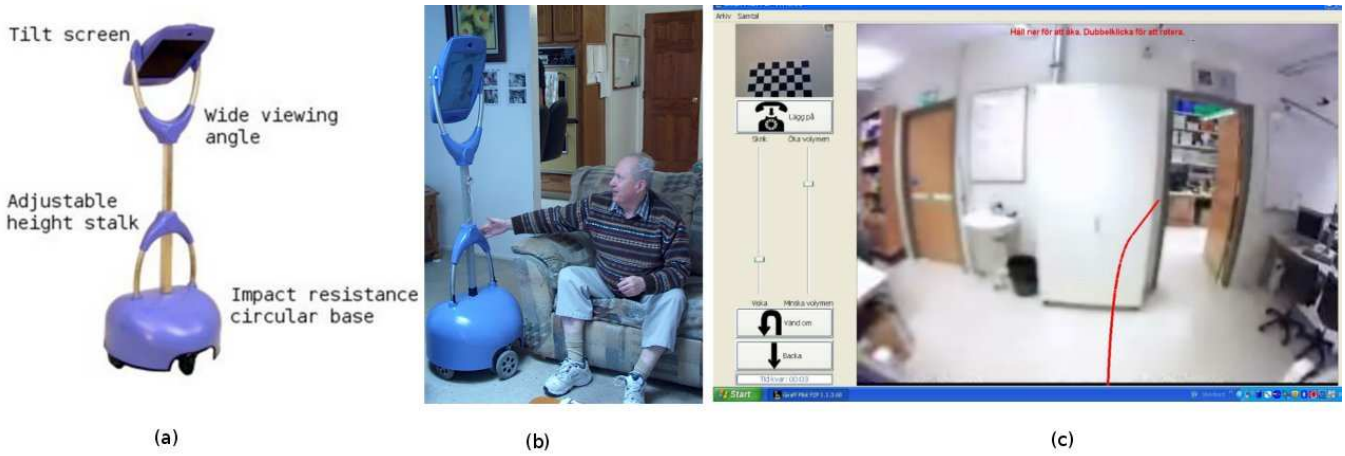


**Figure 1: (a) A picture of the Giraff platform and (b) an example of interaction. (c) shows a snapshot of the client interface.**

with added mobility controls. That implies the need to assess the usability of the interface's mobility controls as well as the effectiveness of these controls in navigating the robot in its remote location.

### 3.4.2 *Accessibility*

Targeting an audience of people needing assistive technologies implies that the developed tools must be made accessible to people with various special needs. This includes, for instance, people with impaired vision, for which enlarged or high-contrast user interfaces can be employed. Clearly, interfaces should be evaluated as far as possible by the intended end-users of the system in order to reduce the scope of problems after system deployment.

### 3.4.3 *Non-Obtrusiveness*

When using a tool for e.g. medical reminding it is necessary to be proactive. However being too proactive may cause the tool to seem obtrusive. The balance between proactiveness and unobtrusiveness is delicate, and it has been recognized that attitudes in this dimension can vary quite significantly between different cultural contexts [1].

## 3.5 Privacy and acceptance

Naturally the aspect of privacy has to be dealt with when dealing with robotic telepresence or any system that could be connected to from outside. It is always a concern whenever computers are used to store data or to monitor activity [15]. Preventing unauthorized access to the Giraff and making the users feel certain they are not being watched are issues that must be evaluated in the study. It is a possibility that the appearance of the robot might affect user perception and willingness to use the robot. Therefore, asking the users about the appearance of the robot is important in the study. It has been shown [16] that people at different stages of their lifespan show very divergent opinions and preferences. Particularly, the elderly indicated a preference for a small robot, hardly resembling a human being, which has to intrude as little as possible in personal and domestic life; a device which is non-autonomous seemed to be preferred. The results reported in [16] clearly outlined different levels of perceived utility and acceptability of a technological aid supporting the elderly in performing everyday activities.

Research about the influence of perceived enjoyment on acceptance [6] indicates that this factor needs to be part of an acceptance model applied to robotic systems to be used by elderly people. The study described in [21] confirms two hypotheses: (1) the more people perceive a robotic system to be enjoyable, the more they intend to use it and (2) the more people indicate they intend to use a robotic system, the more they will actually use it.

As mentioned above, there are different levels of perceived utility and acceptability of a technological aid for supporting the elderly in performing everyday activities. It is important to underscore that the overall aim of the device studied by the ExCITE project is not to not replace everyday activities performed by the elderly, rather to alleviate social isolation and increase the ability of caregivers to provide assistance remotely. Hence, the system should not be perceived as a threat to self-efficacy.

## 3.6 The Evaluation/Refinement Cycle

In total, Giraff will be deployed at twelve end-user sites using a user-centered approach allowing for one incremental redeployment of the prototype at each test-site for prototyping, validating and refining. A graphical depiction of the cyclic approach is shown in Fig. 2. The beginning of each cycle has three test-sites (one each for Italy, Spain and Sweden). The schedule for the user evaluations that will occur during the ExCITE project is illustrated in Fig. 3.

After a period of six months the first user evaluation for each test cycle is finished in which we plan to elicit functional user requirements such as aestetics, space limitations in the homes of the elderly, need for technical improvements and new ideas for the robot as well as the psychological perception of the system and how it has affected the feeling of loneliness and isolation as well as social and familiar support. The prototype is either refined incorporating suggested changes based on the user feedback or replaced by a newer prototype. Simultaneously, a new test cycle using the

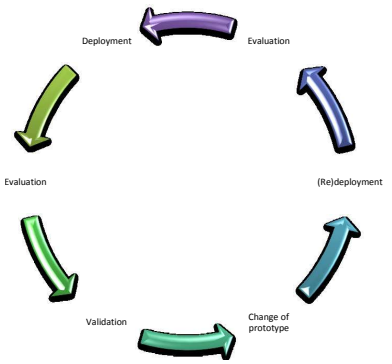


**Figure 2: A simplified version of the cyclic methodology employed within ExCITE.**


**Figure 3: The project ExCITE evaluation schemata. Month 1 is July 2010.**

cyclic approach as in Fig. 2 consisting of three new test sites begins. When closing up to twelve months for a test-site, the users will be asked to both evaluate the second prototype as well as to give their preference to one or the other of the deployed prototypes. It may of course also be the case that a mix of functionalities or design in the deployed prototypes is what is preferred.

Apart from considering the end-user and client-user feedback we also plan to focus on endowing the robot with basic functionalities for autonomy in order to strengthen its at home behavior and to support remote navigation such as aid to drive in to the docking station and stairs detection. It is our aim to incorporate these new versions of the Giraff into the user-evaluation cycle to assess their acceptance.

### *3.6.1 A description of the first Swedish Test-Site*

In this section, we provide a brief description of the first test site in Sweden. At this test-site, an elderly couple is living in their own house outside the city of Örebro. The couple receives several daily visits from a healthcare service called "Hemtjänst". Hemtjänst is a domestic care service that is freely provided by the Swedish municipalities. Through this service, elderly citizens receive assistance at home from health care professionals according to their individual needs (e.g. assistance cleaning, reminding services etc). Further, these needs can vary and be adapted and may include sporadic visits or even several visits a day to an elderly person. The couple at the test-site also uses a security

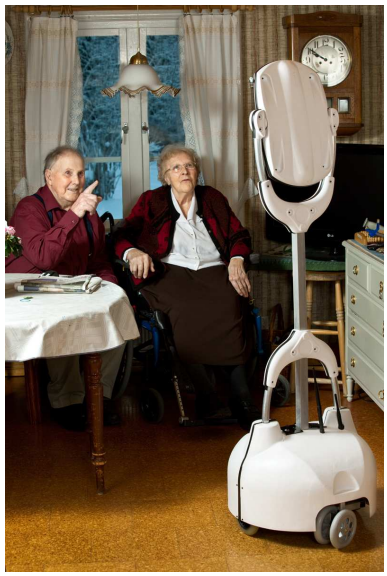

**Figure 4: The first swedish test-site is the home of an elderly couple who require some level of assistance. The Giraff is facing the elderly couple as they discuss with the healthcare personel.**

alarm service allowing them to, at any time, press the alarm button and get immediate contact with an alarm operator who can alarm the health care providers. Further, the couple also have relatives who are living in another city (approx. 200 km away) with which they would like to keep a more socially expressive contact than what can occur during a regular phone call. To enable the Giraff platform to work at the home of the couple, basic internet services were installed in the home. This was the only required infrastructure change necessary. In this particular test-site, the elderly woman was confined to a wheelchair and the home was adapted with ramps and thresholds were removed. Therefore, the Giraff platform can effectively navigate to the same locations as its inhabitants. An organizational approach to selecting this test-site was taken. In other words, it was through contact via "Hemtjänst" and the alarm service provider that the ExCITE team selected this couple as a first trial. At the offices of "Hemtjänst" and the alarm service, the client software was installed and where necessary workstations were provided with cameras and headsets. The first prototype deployed is shown in Fig. 4. The refinement phase is soon to commence and a new prototype will be deployed to the couple. This prototype includes added features such as a button to accept/reject calls which is not only virtually possible but also two analog buttons placed directly on the Giraff body. A more robust casing is also used as well as the addition of a handle which allows users to easier pick up the Giraff if needed.

## 4. DISCUSSION: TOWARDS A METHODOLOGY FOR EVALUATION

Within ExCITE we are developing a number of tools with which it is possible to measure and evaluate the parameters detailed in the previous section. Primarily, ad hoc questionnaires are used which focus on extracting the relevant

measures. A scientific novelty in this project will be to investigate how these tools are effective in understanding not only the relevant parameters but also how these parameters are affected by longitudinal study as well as the potential risks that are inherent in the design of the test-site and deployment strategy.

## 4.1 Tools for Evaluation

From an end-user perspective, the evaluation is focused on usability, user acceptance and perceived social isolation or loneliness. One model to assess acceptance of assistive social agent technologies by older adults is the Almere Model [5] which is inspired by the more reknowned TAM [2] and UTAUT [19]. Almere suggests that Intention to Use is determined by perceived usefulness, perceived ease of use, attitude, perceived enjoyment and social influence. The model also suggests that Use is determined by intention to use and influenced by social influence and facilitating conditions. What the model does not incorporate are the moderating factors in UTAUT namely: age, gender, experience and voluntariness. It is our belief that these moderating factors will moderate how the system is perceived by different organizational units. However it is also important to investigate the elderly social participation, isolation, social and familiar support and how this may be changed when using the Giraff and whether these changes tend to last or if the social structures go back to their previous states.

From a client-perspective, the evaluation is mainly related to usability of the client interface and its navigation methods. It is important to ensure that the system is easy and safe to use. However, also psychosocial factors have to be included to measure the degree of user acceptance for the different potential users. Personality, motivation to use, enjoyment as well as whether or not the system is naturally fitting in to previous working habits for e.g. health care professionals are all important factors for actual use.

Time is what links Intention to Use and Actual use in TAM, UTAUT and the Almere model and is one of the important factors that need to be considered in relation to how a robot fits into an existing context with social structures. Time can help to highlight the extent of influence and serve as a trajectory of how the social structures vary and evolve [22]. Previous research has shown that while robots may have an impact on social structures when initially deployed, social structures go back to their previous states when the novelty effect wears off [7, 8]. However, as time passes an emotional bond between human and robot may grow as is the case when people name their Roomba vacuum cleaner robots [18].

## 4.2 Risks

The cyclic evaluation cycle as well as the strategy to deploy test-sites are not risk free. Aside from the obvious technical challenges a number of risks have been identified already at the beginning of the project as well as after the first deployment at the swedish test-site described above. Below we outline a three of the key risks that have emerged from the first test site deployment:

- Low use-worthiness - The deployment of a Giraff will likely cause initial changes in the social structure for the end-user as well as the client-user. As the Giraff encounter is expected to be the first time of ICT-use for the majority of the elderly involved in this study, it is likely that there is a high technological interest upon introduction to the system. However, it is crucial here that the prototype deployed is usable from day without technical problems since these may influence the user's initial trust in the technology as well as their enjoyment. A simple example from the first test site were problems with the docking station which led to the fact that when the robot discharged its battery and switched off, the couple did not realise how to charge the unit and therefore seized to use the unit for an extended period before requesting help. While these technical glitches can be easily overcome by placing adequate resources to ensure functionality, there must in turn be a high use-worthiness to ensure that the unit will be employed. The concept of use-worthiness has been studied in [3].

- Feedback Loop -Technical risk lie in the speed of the feedback loop that connects the chain of user input, team assessment, redesign, prototype modifications and redeployment (for the next cycle of user input). Maintaining the speed of this loop has a major impact on overall schedule of the project, and an important and seemingly simple change from user requirements could necessitate procurement of new parts or fabrication processes with long lead times. Within ExCITE we have attempted to foresee this issue by using the Giraff platform whose "overkill" philosophy minimizes hardware changes with longer lead times. It is also necessary in the evaluation to adequately match user feedback to technological needs. For example, a simple change where the Giraff docks with the screen and camera facing the wall already adds an enhanced sense of privacy and assurance that when docked the elderly are not observed.

- Organizational Perspective - Interoperability issues from social and organizational point of view are needed as lack of interest from one of the organizational unit involved could impede the evaluations. Consequently, cultural influences, language barriers and in particular organisational issues related to healthcare need to be understood and accounted for both locally and on a european level. While, it is the ambition of the project to make explicit the correlation between factors such as organization participation and user acceptance of the embodied telepresence, it is also necessary to add a greater awareness of indirect influences of the policy makers to the individual member states and its citizens. Support from the organizations is needed at an early stage as it effects all levels of the project. At the lowest level, without organizational support, there is a greater risk that the unit is simply underused and threatens the validity of the evaluations.

# 5. CONCLUSIONS

This paper has presented the overall methodology in the ExCITE project which adopts the philosophy that end users' feedback is necessary in the early development phases of the prototype in order to reach a marketable solution. The methodology described is based on a cyclic user-validation

loop where feedback from the users is considered and re-evaluated. User feedback is gathered from evaluations that are performed in-situ, on a reasonable scale and with a longitudinal perspective. The longitudinal aspect of the user based evaluation allows a better understanding of important parameters such as user acceptance, added value of social interaction, integration in a domestic environment, technical viability and scalability. A discussion of the suitable tools used for evaluation as well as the potential risks within the project have been lifted. In addition, a description of the first test site which has been deployed in Sweden was briefly outlined.

## 6. ACKNOWLEDGMENTS

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