A network-based approach for evaluating ambient assisted living (AAL) technologies.

Abstract.

Ambient assisted living (AAL) technologies could support people experiencing physical or cognitive challenges, to and maintain social identities and complex activities of daily living. Although there has been substantial investment in developing AAL innovation, less effort has been devoted to understanding how to evaluate the impact of AAL on physical and mental health. Taking a theory-based evaluation approach, we suggest that AAL technologies rely on networks of people and organisations to function, and analysing the changing structure of networks can bridge the gap between socio-technological change and individual-level capabilities. We present conceptual arguments for taking a network perspective in AAL evaluations, illustrated with examples from our own group's work on technology use among older people with cognitive impairments. We then discuss the different evaluation questions that could be addressed by 'ego-centred' and 'global' network analysis. Finally, recognising the creative ways people mobilise technology for themselves, and the unanticipated effects of technology, we underline the importance of qualitative, observational, and ethnographic approaches in unpicking the processes of change brought about when new technologies are introduced.

Keywords: Social network analysis; ambient assisted living; technology evaluation; information and communication technology; theory-based evaluation; health technology; older adults

Background

In the last decade, ambient assisted living (AAL) has emerged as a compelling vision of sensitive, responsive data processing technologies embedded through the lived environment, supporting complex activities of daily living and enabling older adults to remain in their own homes for longer (EU AAL Joint Programme, 2014; Costa et al. 2009; Rashidi and Mihailidis, 2013; Sun et al. 2009). AAL technologies include mobile and wearable sensors, assistive robots, and so-called 'smart homes' (Rashidi and Mihailidis, 2013), and they span usage domains including everyday activity support, activity monitoring, and access to health care services (EU AAL Joint Programme, 2014). This class of technology is a fuzzy set, with multiple definitions available. Gersch et al. (2010) describe AAL as "'intelligent environments' [that] aim to compensate predominantly age-related functional limitations of different target groups – through technological information and communication support in everyday life," while the AALIANCE group (van den Broek et al. 2010) suggest a more general definition: "intelligent systems of assistance for a better, healthier and safer life in the preferred living environment". This broader definition could include a variety of off-the-shelf technologies used by people to support daily activities – such as smart phones, automated diaries, navigation systems, and social networking websites. For the sake of clarity, and for pragmatic reasons, we come closer to the second definition in this article. As we go on to discuss, there have been significant problems with attempts to develop truly intelligent environments – therefore, our own empirical work has focused on how older people put available technologies to use for themselves.

The aspiration to develop intelligent, responsive environments has been around for some time. In an influential essay, the computer scientist Mark Weisbrot (1999) foresaw a world of ambient computing in which the 'traditional' model of ICT – people using input and output media such as keyboards, mice, etc – is replaced with an ambient computing

landscape. In this new technological world, we would be able to communicate directly with sensors embedded in our homes, furniture, phones, vehicles, and pens, and the sensors would be able to communicate with each other. Certainly, important developments in 'smart' objects and ambient intelligence have been emerging in the last decade (Katz and Fitzeck, 2007). Meanwhile, the ability of ICT innovations to support health care delivery at a distance is increasingly being mobilised (e.g. Brownsell and Bradley, 2003; Department of Health, 2011; Johansson and Wild, 2010; Pandor et al. 2013), and a body of literature on older adults' use of ICTs for maintaining identity, social relationships, and enjoyment has been emerging (e.g. Astell, 2013; Astell et al. 2010; Hedman, 2015; Rosenberg and Nygård, 2013). Nevertheless, it is clear we are still some way from developing fully integrated, responsive AAL systems. 'Caring environments', in which sensors anticipate and respond intelligently to human behaviour, have seldom been taken beyond the prototype stage. Dourish and Bell (2011) argued that we should abandon this vision altogether. The notion of caring environments, in their view, relies on a belief in a 'proximate future', in which all the glitches, interoperability problems, and bugs have been ironed out. Contra this 'techno-utopian' perspective, it has been argued that human behaviours and social contexts are too complex, subtle, fluid, and subjective to be practically condensed into algorithms (Rogers, 2006) – and so we should focus on developing and evaluating ICT innovations that deliver small but important differences in the here and now (José, et al. 2010). Others have suggested we need to pay more attention to the ethical and social implications of AAL and other related ICTs (Greenhalgh et al., 2015; Mort et al., 2013), and have lamented a narrow focus on 'socio-functionalist' attributes such as usability and acceptability in technology evaluations (Mortenson et al., 2015). This article builds on these ideas, suggesting that networks are helpful units of analysis for AAL evaluations, and that the technologies 'work' to the extent

that they can support people, within their networks, to achieve the "beings and doings" (Sen, 1999) that they value.

The AAL concept developed in the context of an aging society: Approximately 22.5% of people living in the EU are aged 65 or older, a figure which is projected to increase to 30% by 2050 (Eurostat, 2008). One striking aspect of the demographic shift is the increase in the so-called 'oldest old' in Western countries. People over 90 years of age are set to be the fastest growing group in the USA in the next century (Corrada et al. 2010), while Europe has been identified as the oldest continent in the world (United Nations, 2009), with Rau et al. (2013) estimating that 91% of new-born baby girls in Sweden will reach 65 years of age, of whom 75% will go on to celebrate their 80th birthdays. Many fear that as people live longer, the numbers living with an increasing range of cognitive and physical impairments will also grow, with the resulting demand for long-term care outstripping available resources (Lancet, 2003). Additionally, informal caregiving is becoming increasingly important in the health and social care landscape, with approximately 10% of residents in England and Wales providing some sort of informal care for family members, friends, or neighbours with disabilities (Office for National Statistics, 2013). In light of such data, it is frequently argued that we need radical, new, and innovative solutions for healthcare delivery in the 21st Century.

Although pessimistic views on this greying demographic have not gone unchallenged (e.g. Angus and Reeve, 2006; Moody, 2013), AAL has come to be positioned in various ways as a solution for this "problem". Sun et al. (2009) suggest most efforts in AAL development are driven by the desire to construct a "safety environment" to keep people in their own homes and to reduce the burden on public services. On the other hand, Costa et al. (2009) draw on ideals of empowerment to describe a responsive digitised landscape which has knowledge of users' habits and preferred ways of doing daily tasks. The EU's Joint AAL Programme – a major funder of research in this area – takes something from both these

views. AAL, according to the Joint AAL Programme (2014) comprises "innovative ICT-based products, services, and systems for the process of aging well at home, in the community and at work, therefore improving the quality of life, autonomy, the participation in social life, skills, and employability of older people and reducing the costs for health and social care". Hence, AAL is seen in terms of enhancing people's everyday lives, yet a "burden" discourse is maintained vis-à-vis older people, who are seen to impose unaffordable costs on overstretched health care services (Vines et al., 2015). This is somewhat at odds with the perspectives of older technology users themselves, who tend to adopt technologies to support the activities they personally value (Hedman, 2015), or to have fun (Astell, 2013).

The remainder of this paper is structured as follows: First, we present a series of conceptual and practical reasons for focusing on networks in AAL evaluations. We then support the case with empirical examples from our own work on older people's everyday technology use. Following this, we move on to offer guidance on when and how to apply 'ego-centred' and 'global' network analyses to different questions in technology evaluations. Finally, we discuss the importance of qualitative process evaluations in unpacking the psychosocial impact of new technology-enabled network structures.

Why we should think of AAL in terms of networks: Conceptual and empirical arguments

The evaluation approach we want to develop in this paper comes from the tradition of theory-based evaluation (Stame, 2004; Walshe, 2007), which suggests that our choice of methods should be driven by a sound conceptual understanding of the characteristics of the phenomenon under investigation. With this in mind, our basic contention is that AAL products and services should be understood as technologies that both depend upon and reshape social networks – even if the technology is primarily individually-oriented. Networks, in the sense we understand them in this article, involve nodes – especially people and organisations – that are linked up over time and place by information processing and

communication technologies (see Castells, 2000, especially chapter 6, for an informative discussion of this concept). Applying network theory to evaluate ICT innovations in the health care space has some precedent (Greenhalgh et al. 2015; Introcaso, 2005; Mort et al. 2013); and network analysis mirrors the logic of AAL innovations themselves, which depend on the reliable relay of data between sensors, people, and the lived environment. The network connected by a single AAL technology might include engineers, health and social care professionals, researchers, health service commissioners, service providers, people with physical or cognitive impairments and their friends and family. All these social actors will emphasise different markers of 'success' in an AAL-based programme, and, furthermore, are themselves engaged in a series of dynamic relationships. Last but by no means least, the growing body of literature suggesting strong associations between loneliness and mental and physical health problems in later life (Alpass and Neville, 2003; Luanaigh and Lawlor, 2008; Luo et al., 2012), and the emerging approaches of using technology to support relationships in challenging contexts (Alm et al., 2007; Astell et al. 2010) suggests a compelling case to focus on the link between individual-level capabilities and the social networks in which they are supported and expressed.

Empirical work on older people's uses of technology also lends support to focusing on networks in technology evaluation studies. Our research group have been working with people diagnosed with mild cognitive impairment (MCI) – a condition which some see as a prime space for the deployment of AAL – and their narratives support the idea that networks are essential in informing how and why they adopt technologies (for detailed discussions of MCI, see, e.g. Petersen, 1999; Gomersall et al., 2015; Werner and Korkzyn, 2008). In a recent literature review, we found that people with MCI generally want to master activities for one or more of four reasons, all of which had important social components: 1) To convey social values; 2) to support significant roles, 3) to reduce the negative impact of the illness on

their friends and family, and 4) to stay safe and healthy (REF REMOVED TO PROTECT AUTHOR ANONYMITY). In other words, this group of participants valued outcomes that went beyond the individual level, and recognised the relational and social implications of managing their cognitive impairments.

In a separate series of in-depth interviews with people with MCI and their close family members residing in the UK, we found most of our participants had examples of valued social activities they had either given up on, or were finding increasingly difficult. These included doing administration for local clubs, going to craft classes, or going on fishing or other sports trips with friends (see also Blieszner et al. 2008; Lingler et al. 2006). Supporting people's involvement in such activities has been cited as one area where AAL technologies could help, for example through route planning, intelligent guidance, and security risk systems, such as fall detectors (Pieper et al., 2011, EU Joint AAL Programme, 2014), and there is evidence that older people's keenness to adopt new technologies is heavily influenced by whether the technology can support valued occupational needs (Hedman, 2015) and personal identities (Astell et al. 2014). Because these objectives are particular to the person, it would be a mistake to treat an AAL product as a single "intervention", and the search for common "outcomes" of relevance to older technology users is likely to be in vain. This implies a shift away from a clinical trials model of technology evaluation, and toward studies of technology-in-use (Greenhalgh, et al. 2015) – that is, ethnographic, observational, real-world research – to understand how people utilise technology creatively, in the context of their networks, to achieve their goals.

Taking this technology-in-use perspective on AAL technologies can provide some interesting insights on how and why real-world uses of technology may differ from those intended by designers. Technology is used to achieve unique, personal ends, and its use is influenced by our social contexts, the (perceived or real) constraints and potentialities of our

bodies, and our own assumptions about technology (see also Nygård, 2008). For example, one of the participants in our research discussed how he used a paper diary[1] to keep track of his social engagements, but also elaborated his concerns about such support:

> A6: Couple of year ago, yeah, a couple of years ago, and I weren't remembering things and…
>
> Interviewer: Like what?
>
> A6: Well, everything. Er… ((rummaging through paper / files)) where's the book gone? No, not there, no no no. Oh there you are. I mean this was it
>
> Interviewer: So you have a diary and you keep everything in that diary – but it looks like you've always done that, that's not a new thing is it?
>
> A6: Yeah but I think it stopped my memory working. Er… I didn't use, I used to put lots of things in, yeah, football matches predominantly
>
> Interviewer: Do you think you relied on it too much, is that what you're saying?
>
> A6: Yeah, yeah. I think I did to be honest (60-year-old man with MCI diagnosis)

For this participant, supporting his social activities with the diary was evidently a mixed blessing. It certainly seems as though the diary helped him organise his life and keep up to his social engagements – again, highlighting the importance of networks in evaluation studies. And yet, in stark contrast to discourses which propose AAL as a way to promote "independence" among people with cognitive impairments, our participant was concerned about becoming too passive, too reliant on the technology; thus allowing his memory to decline further. Interestingly, this participant's wife expressed exactly the same concern that

[1] Although paper diaries of this sort are much more 'lo-tec' than AAL technologies, automated reminder systems are an example of AAL. Given the increased automation of such systems, this arguably makes our participant's reflections on over-reliance even more pertinent.

her husband would "use or lose" his capacity to plan and manage his social life. A similar example was also seen at a recent knowledge café in a residential facility in British Colombia, Canada, in which our group presented the idea of smart home technologies to the residents, using Smart Things (www.smartthings.com) as an example. One common thread among the responses to this product was worry about becoming too dependent on the technology, and the prospect it could be used as a way to replace existing human-to-human support systems. In fact, even if an AAL technology operates faultlessly at a technical level, we have found that face-to-face contact can underpin how well a technology 'works' for an individual – that is, there needs to be a pre-existing social infrastructure to support beneficial technology use. For example, when one participant, 'B5', was asked to recall when she first noticed a change in her mother, she spoke about her habit of locking herself out of her home:

> "B5: [I]t was when she lived in other flat what I told you about down, when she were upstairs. She, cos there were a post office across the road, and thank god that she knew these and she always went there a lot, this has got to be I think she was at the memory clinic, two years I think I can't remember now, and it's got to be a couple of years before that, cos I said to her, you have got to go to the doctors because she kept locking herself out, so she, luckily she knew my phone number so they'd ring me up and say 'Beth your mums locked herself out again' so, do you know what I mean and am like, she is forgetting, she is coming out of the house without her keys…" (42-year-old woman; daughter of 78-year-old woman with MCI diagnosis)

This short narrative gives a good indication of how ICTs can be used to link up a network to support a person's activity. First, it is important to note that this participant's mother particularly enjoyed walking as a way to get some exercise. In our separate interview with her, she told us that she 'loved' walking, and tried to have a walk every day to stay active. So, from a capability perspective, we could say technology was beneficial in terms of our participant's desire to maintain one of the 'doings' that she has reason to value. However, it is

not the phone itself that ensures her safe return home, but the *use* of the phone by the post office staff to link up other people in the network: any benefits gleaned from the technology depend on human contact. The nature of the relationships between the people in the network are vital, too: It is important this daughter lives nearby to her mother; that she does not go to work; that she has her own set of keys; that the post office is nearby, and that both women have good relationships with the post office staff. Technology plays a crucial role in facilitating this particular network involving B5, her mother, and the post office staff; but it is not the technology itself that produces the outcome of the person's safe and timely return home. That is achieved by people using technology to mobilise their networks over time and place, exchanging knowledge and information to support those they care about. In this sense, evaluations can benefit by moving beyond the individual-level, to understand how technology produces effects at the level of the person's support network, and what kinds of network are needed for the technology to be beneficial to a person.

FIGURE 1 ABOUT HERE.

Figure 1 schematically represents the network links required to ensure the safe return home of our participant's mother. The white arrow represents human-to-human contact, while the black arrows represent connections that depend upon a networking technology. This approach of analysing the network required to achieve a specific activity can give some insight into how and why technologies could build beneficial connections between people and places. However, it would be an over-simplification to suggest the use of the phone here is empowering, or, in itself, leads to an optimal outcome. Rather, a series of complex, conflicting effects ripple through this network with the introduction of a communication technology. Perhaps most importantly, the mother's forgetfulness has an impact on her daughter, who must come out to assist her. The choice of language in B5's narrative ("thank God she knew these", "you have got to go to the doctor's", "*luckily* she knew my phone

number") suggests she was experiencing anxiety, and the presence of the network only goes part way to resolving this for her: later in the interview, this participant rhetorically asked what her mother would do "if I'm on holiday and you lock yourself out". Indeed, there are a number of things that could go wrong in the process of unlocking the door: the mother may lock herself out when the post office is closed, the daughter may be away in another city when it happens, her phone may have run out of battery, and so on. In other words, this network is an unreliable way to support the participant's mother on her walks. In cases like this, AAL technologies adapted to the person could be of particular use – for example, a door sensor that can alert the participant when she has locked herself out of the house, and release the latch when instructed from a mobile phone. In such a case, the technology would be *replacing* an unstable and complex network with a simple technology to do the same job. Although such a technological support could be beneficial in terms of efficiency and safety, it is important these are not the only criteria we use in evaluations. As we go on to discuss in the final section of this article, we also need to understand the subjective effects of new network structures on the individual – and there is reason to exercise caution when human support systems could be replaced with technologies (Beedholm et al., 2015; Mort et al. 2013).

Local and global network evaluations

Networks have a tendency to multiply complexity and uncertainty (Castells, 2000), and this has important implications for AAL evaluation. Since networks are fluid, open systems, and each part of the network is a potential 'active ingredient' in bringing about change, the intervention 'black box' (Pawson, 2006) expands with every node added into the network, and every bit of data transferred between network nodes. Furthermore, we cannot know in advance what the truly important effects of an AAL product or service will be, since these

emerge in real-time interaction between the person, their social contacts, and the AAL technology (Greenhalgh et al. 2015).

Traditional, methods-based evaluation approaches, particularly randomised controlled trials (RCTs), are ill-suited to making sense of complexity of this sort. Typically RCTs assume that, by assigning participants randomly to 'intervention' and 'control' groups, and looking for statistically significant differences between the groups on a *priori* endpoints, researchers can draw robust conclusions based on counterfactual evidence – that is, we are able to perceive the difference between what happens when an intervention is or is not present, and randomisation protects against the 'noise' of random variation unduly influencing results. However, this focus on controllability, repeatability, and predefined outcomes can be a serious impediment to understanding how socio-technological interventions like AAL pan out in the complex, heterogeneous, and emergent social world we inhabit (Greenhalgh, 2012; Greenhalgh et al. 2014; Mowles, 2008, 2014, 2015; Pawson, 2006; Pawson and Tilley, 1997; Stame, 2004). In the context of technology evaluations in developed countries, true experimental control is difficult if not impossible to achieve, since people increasingly use technology to support daily activities irrespective of their enrolment in trials (Hedman, 2015; Rosenberg and Nygård, 2013). Network-based evaluations, by contrast, recognise the dynamic, changing nature of social relationships, and, through focusing on processes of change, can help isolate possible causal pathways through which health technologies produce their effects (Davies, 2005). In addition, a focus on networks mirrors the logic of many AAL technologies insofar as:

- AAL technologies depend on networking processes – particularly the transfer of information between people and organisations. In addition, with the decentralised, fluid, and complex model of AAL provision, it is important to examine the effects of different network structures on economic, psychosocial, and health domains.

- Technologies shape, and are shaped by, social relationships and practices – even when the focus is solely on the individual activities of the "end user". As scholars in the emerging field of psychosocial studies have argued, we cannot neatly separate out psychological and social domains (Frosh and Baraitser, 2008), and so our evaluations, too, need to understand these levels synthetically. In analysing networks, the focus shifts from individuals to the relationships between them. Depending on the type of network analysis used, researchers may also examine the broader social, political, and economic contexts in which people act.
- Social connectedness is a fundamental component of health and wellbeing, and so alongside individual-level components of wellbeing (self-esteem, daily activities, self-reported mental and physical health, etc), it is important to understand how technologies affect this.

However, while there is a compelling conceptual case for using network analysis in AAL evaluations, what exactly is meant by a network varies according to the research context, and several taxonomies of networks are available (Davies, 2005; Monge and Contractor, 2003; Scott, 2000). Although reiterating the full range of network definitions and analytical methodologies is beyond the scope of this paper, we suggest there are two interlinked questions that evaluators might consider to inform their approach: 1. What is the level at which the network evaluation takes place? And, 2. What markers of 'success' is the evaluator interested in? With respect to the first question, researchers have contrasted "ego-centred" and global network analyses (Bearman et al., 2004). Ego-centred network analysis focuses on the local networks in which individuals are embedded, and network diagrams can be elicited through methods such as narrative interviews or eco-maps (discussed further below). By contrast, global network diagrams can be created using large-scale survey methods to elicit the links between all the members in a network. The analytical focus in a

global network analysis moves from the linkages between one individual and their network, to the nature and strength of *all* the connections throughout a given network (Scott, 2000). Although the focus here is broader, researchers nevertheless need to be clear about what exactly is meant by 'all the members in a network', and how the definition of this relates to the research question. With respect to the second question, since AAL is typically proposed as a healthcare intervention, the focus would typically be on indicators of psychosocial or physiological health, or healthcare resource use, and local and global network analyses can address different dimensions of these. While ego-centred network analyses can reveal how individual capabilities are supported or constrained by new local network structures, global analyses can explore questions pertaining to diffusion of innovation, inter-organisational linkages, and health economic and epidemiological questions (Table 1). Investigators might wish to hone in on how a network enables a specific activity, as we did in the previous section of this article, but we might also wish to understand what kind of network structures are needed to support a range of different activities; what subjective effects AAL technologies engender in users; or how the introduction of an AAL-based network affects workflow, efficiency, and chains of responsibility at an organisational level. The specific blend analytical tools brought to bear on an evaluation should be guided by considering research priorities and user needs.

TABLE 1 ABOUT HERE

Whether an evaluation is taking place at a local or global level, network diagrams can be created to represent the nodes in a network and the linkages between them. Each link in such a diagram can be thought of as a potential mechanism of action, and the analyst can identify the linkages supported or created by an AAL technology, and identify how these linkages might bring about change. Methods for creating a network diagram from the point of view of health and social care users are simple and well-established. Hartman (1995)

describes ‘eco mapping’ as one way to elicit users’ perceptions of their networks using paper and pen diagrams. In her approach, a series of circles are drawn to represent the person’s connections with family members, health and social care professionals, and wider civic and public institutions (Figure 2). In addition, the nature of relationships can be represented with different types of line drawn for different kinds of connections. Eco maps, then, provide a way to condense a lot of data about people’s social connections into visual diagrams, which can be compared over time to help analyse the impact of AAL technologies. In addition, it is important to unpick the mechanisms enabled by the network to produce change. The importance of process evaluations has long been acknowledged by realist evaluators as a way to glean the ‘active ingredients’ of a programme, and to improve future intervention designs (Pawson and Tilley, 1997; Pawson, 2006). Likewise, understanding socio-technical change by focusing on networks is not only a matter of quantifying network changes over time. Evaluators need to understand the meaning and significance of changes in people’s networks, and this requires methods to delve into the messy, contested terrain of subjectivity and power relations. In the final section of the paper, we will suggest some ways to approach these issues.

FIGURE 2 ABOUT HERE.

The power of networks: Relationality, social change, and the importance of process evaluations

Networks are, by definition, dynamic, relational phenomena. They have been identified as a key source of social capital (e.g. Burt, 2000; Ellison et al., 2007) and of shifting power relations and social change (Castells, 2000, 2003, 2007). AAL technologies themselves can be understood as organising forms for what Castells (2000) calls “the space of flows” – the virtual infrastructure through which information is dispersed among people across time and place. Since these networking processes have profound effects on socioeconomic systems

(Castells, 2000) and personal identity (Castells, 2000), it is important to understand how AAL, when used to promote health and wellbeing, brings about change not only for the individual "end user", but also for those around them, and for wider social and economic systems.

As we discussed earlier in this paper, real-world technology use is often idiosyncratic and unpredictable, and people use technologies to achieve a wide variety of personal and social ends which evaluators are unlikely to anticipate. One recent case study (Astell et al., 2014), showed a man with dementia regaining several activities and roles through his use of a smart phone. Brian learned to use the technology primarily through one-to-one training by a member of the research team, and it was the interweaving of the technology among wider networks that led to change: from the individual contact with the researcher herself, to the networks of researchers and clinicians in which Brian went to speak about his smartphone use. The investment of time was high but the benefits to his life and well-being were incalculable (see Brian's blog: http://cobaltproject.net/). Furthermore, when the impacts of technologies evolve in tandem with those who are developing and using them, it becomes problematic to attempt to distil the impact of technology into neat, unidirectional causal effects. It is increasingly recognised that complexity and nonlinearity is a basic feature of social life, and consequently, several different ways of conceptualising and dealing with complexity in evaluation science have been proposed (Mowles, 2014). While network analysis can provide a helpful aid in the evaluator's toolkit, and has indeed been suggested as an approach for modelling dynamic change over time (Davies, 2005), observing these changes can take us only so far if we want a satisfactory understanding of the impact of AAL technologies on health and well-being. We also need to pair the network analysis with an understanding of the intentionalities of the social actors in the network, and how these interweave to produce effects (Mowles, 2015). This requires methods capable of delving into

the subjective experience of AAL "end users", as well as the power relations between network actors, and the political and economic context in which technologies are created and used.

This is important from an evaluation point of view, because the most significant impacts of AAL technologies may be missed if we only focus on *a priori* indicators of "success". Whether a technology is designed for care, or simply for living, it is possible for the technology to be empowering or disempowering; to expand or constrain a person's living space. On the one hand, technology can enable a person to have more agency in their world (Astell et al. 2014, 2015; Heidegger, 1962; Ihde, 1990). Conversely, technology, especially when produced for political ends, can limit agency (Greenhalgh, 2012; Greenhalgh et al. 2014), or even serve to contribute to the construction of the "problem" it purports to solve (Beedholm et al., 2015). Sometimes, technology can simultaneously empower and disempower, as Mol's (2000) ground breaking research on diabetes monitoring devices showed. Understanding the effects of technology on personal agency and power relations is especially pertinent in AAL evaluations, since concerns have been expressed about the implications of monitoring technologies for privacy and autonomy (Reder et al. 2010), and researchers have questioned the wisdom of attempting to make the home resemble a hospital (Greenhalgh et al. 2015). Mortenson, et al. (2015) coined the term "individualised total institutions" (p. 520) to describe a felt pervasiveness of some forms of home-based monitoring. They argue that, by monitoring an individual remotely with ICTs, a new kind of power relationship is created between the observer and the observed. These changes in the relationships between health and social care users, their families, and health professionals can produce some interesting behavioural and emotional effects. For example, potential AAL users may have a sense of 'being watched' even if a monitoring system does not include cameras (Percival and Hanson, 2006; Sixsmith and Sixsmith, 2000) – and indeed, at our

recent knowledge café with older adults, the participants used adjectives such as "creepy" and "Big Brother" to describe their perceptions of smart home technologies.

For these reasons, we suggest with Greenhalgh et al. (2014, 2015), and Beedholdm et al (2015), that ethnographic and other qualitative methods are needed to understand the subjective, psychosocial effects of AAL-supported networks. For example, observational methods can be used to ascertain the extent to which a person enjoys using a technology with others (Astell, 2013; Astell et al. 2010), while narrative analysis is a longstanding approach to understanding the link between the personal, the political, and the relationships that make up a person's life (e.g. Bell, 1999; Gomersall and Madill, 2014; Hollway and Jefferson, 2000; Riessman, 2003). Working between this psychosocial, subjective level of analysis, and the broader network structures created by new technologies, offers a way of exploring the paradoxical link between local and global patterns that has long preoccupied evaluation scholars.

Conclusion

AAL technologies have been proposed as a way to manage increasing healthcare costs, to provide more responsive real-time support for people with chronic illness and disabilities, and to enable older people to remain "independent" in their own homes. However, the idea of truly automated, responsive, and intelligent environments functioning without human input is unlikely to be realised in the near future. Instead, we propose ICT innovations are helpful in achieving the hoped-for objectives to the extent that they facilitate beneficial, real-time network linkages between service users, clinicians, informal carers, and service providers. Taking a network-based perspective when evaluating assistive ICT-based innovations enables evaluators to examine processes of change brought about with the introduction of new technologies (see also Davies, 2005). In addition, network analyses can be paired with in-depth qualitative methods to analyse the effects of AAL technology at multiple levels: from

understanding the subjective, psychosocial effects on individual technology users, to analysing global changes in organisational structures and workflows, to unpacking the power relationships created with new technologies.

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