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eFRIEND: an Ethical Framework for Intelligent Environments Development

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Abstract

Intelligent environments aim to provide context-sensitive services to humans in the physical spaces in which they work and live. While the ethical dimensions of these systems have been considered, this is an aspect which requires further analysis. A literature review shows that these approaches are disconnected from each other, and that they are making little impact on real systems being built. This article provides a solution to both of these problems. It synthesises the ethical issues addressed by previous work and highlights other important concerns which have been overlooked so far. Furthermore, it proposes an alternative, more holistic approach that can be used to guide the development of intelligent environments. The validity of the framework is demonstrated by its integration into an actual project.

Keywords

Intelligent Environments; Ethical Principles; Frameworks; User-centred; Multi-user systems

1. Introduction

Intelligent Environments is an area of recent development, and one that shares substantial concepts and objectives with several other fields of recent emergence, such as *ambient intelligence*, *pervasive* and *ubiquitous computing*, and *ambient assisted living* (Augusto et al, 2013a). An intelligent environment can be defined as one in which: -

> "[…] *the actions of numerous networked controllers (controlling different aspects of an environment) is orchestrated by self-programming pre-emptive processes (e.g., intelligent software agents) in such a way as to create an interactive holistic functionality that enhances occupants experiences*" (Augusto et al, 2013a, p. 1)

Intelligent environments are built to assist users to be independent whilst monitoring their state for a variety of conditions. They utilise a range of embedded devices, sensors, biometrics and wearable technology. This paper focuses on ambient assisted living (AAL), an area where there has been an abundance of research, focused particularly on the domains of health and social care in the home environment. More specifically, it looks at the development of intelligent, assistive technologies for one particular user group, young adults with Down`s Syndrome (DS) (POSEIDON, 2014).

There have been several discussions and surveys of the technology behind intelligent environments and ubiquitous computing (Chan el at, 2009; Cook et al, 2009; Wright et al, 2010; Sadri, 2011). The diverse range of applications in this field has been well documented and their many potential benefits acknowledged. While the social and ethical implications of these technologies are often cited as areas of concern, as yet, this area remains relatively undeveloped. Research projects have raised ethical issues, such as privacy and security, but only at a general, abstract level. Such projects invariably conclude by suggesting that further research is required into these issues. Literature reviews in this area often highlight the need for ethical frameworks in research projects, but without specifying in detail what such frameworks might look like.

This paper identifies the main ethical and social issues addressed by previous work as well as highlighting the relevance of other concerns which are important but have been overlooked. These issues are summarised in section 2. In section 3, this literature is narrowed down to those papers that present a framework for addressing ethical issues. A comparative analysis of these frameworks reveals some disparity between them, and, especially concerning for teams developing real systems in this area, a lack of practical use in guiding engineering processes. The findings from sections 2 and 3 are synthesised into a set of core ethical principles which are in turn, translated into practical steps in the development process. An alternative, more holistic, methodology is proposed in section 4, one that includes elements of existing frameworks, but extends these into the engineering process. Finally, in section 5, we demonstrate how this framework has been used to inform the design and development of an actual system to create smart environments which can intelligently provide support to people with DS—the POSEIDON project (POSEIDON, 2014).

2. Surveying Ethical Issues in Intelligent Environments [1]

Privacy is perhaps the single area of greatest concern in intelligent environments and the most frequently cited ethical issue in the literature surveyed (Aarts, 2004; Bohn et al, 2004; Brey, 2005; Van Heerde, 2006, Brown and Adams, 2007; Albrechtslund, 2007; Chan et al, 2009; Oishi et al, 2010; Sadri, 2011; Caire et al, 2014). Privacy concerns are acknowledged as one of the major inhibitors to the adoption and implementation of smart homes, for example, due to concerns around potential breaches of privacy when devices in the home reveal more information than an individual desires. Concerns about privacy flow from the large amounts of personal data that are collected, distributed and exchanged in such systems (Aarts, 2004; Wright et al, 2010; Brey, 2005; Ikonen et al, 2009; Kaasinen et al, 2013). Friedewald et al suggest that ambient intelligence (AmI) increases the amounts of detailed personalized data that is collected, distributed and stored (2005). AmI systems have both monitoring and search capabilities at the very core of their architecture. The ability to combine information from multiple sources is the backbone of any smart system which uses a large variety of different sensor inputs to understand what is happening in any environment (Bohn et al, 2004). Brey argues that ubiquitous computing and the networked character of smart objects, have various unique properties that enhance their privacy risks, including their connectedness, invisibility, increased capacity for memory, sensing ability and potential for profiling, as well as their ubiquity (Brey, 2005). Van Heerde et al note that it is the high *quality* and large *quantity* of data that can be collected that both enable the intelligence of AmI systems while simultaneously posing privacy challenges (2006). It is the fact that this data represents potentially sensitive, personal lifestyle and medical data that has concerned many. The access to, and control of, this personal data, and the potential to misuse and abuse such data, represents a major threat to privacy (Friedewald, 2005; Schulke et al, 2010).

Wright et al argue that AmI technology, by increasing connectivity between different spaces and blurring physical borders in buildings, violates customary privacy boundaries, making it more difficult to escape from being always connected (2010). Langheinrich et al suggest that ubiquitous computing intensifies these problems around *privacy boundaries* by enabling new kinds of flows of personal information which threaten and destabilise such boundaries (2002). The blurring of boundaries between time and space, the recording and storing of many kinds of information in AmI systems and the increased capacity of data mining algorithms; these all have the potential to violate personal expectations about spatial and temporal privacy-protecting borders, as well as expectations concerning the ephemerality and transience of events.

Related concerns have been expressed around the remote monitoring and surveillance capabilities of these AmI systems. The information capabilities that AmI may use to provide sophisticated support for everyday living can also potentially provide an invisible and comprehensive surveillance network (Bohn et al 2004). The opening up of the home by information-generating, permanently-networked technologies has brought with it new surveillance issues for architectural design according to Albrechtslund (2007, p.14), an example being smart systems that monitor household utilities consumption remotely, and that mine data from usage logs. The possibility of monitoring and recording activity in other domains such as retail, shopping, transport, also bring privacy risks (Sadri, 2011). Similarly, context-aware, location-based mobile computing can disclose behaviour and social phenomena such as a user's location, their friends and associates, the timings of interactions, and data accessed. These tools represent an unobtrusive means of collecting data which enable new ways of knowing, representing and reporting of activity. Wright et al introduce a note of caution about AmI applications that

[1] Literature searches were conducted through various specialised and general academic databases. These searches returned a range of different sources, including reports on projects, literature reviews, books, theses, and short articles. Publications that did not address social or ethical issues at all, or were published prior to 2000, were excluded from the sample.

always know where people are, whether family members or mobile workers, and which allow no escape from being always connected and observed (2010).

However, the findings from various projects suggest that users' privacy concerns are by no means uniform, and that these can exist in tension with other priorities, such as the need for safety and security. Coughlin et al, for example, found that service providers and policy advocates were particularly passionate about ethical considerations in smart home technologies, especially trust and privacy issues, 24/7 home monitoring and third party use of behavioural data by commercial entities (Coughlin et al, 2007). However, van Hoof et al in their research into the prototype of a home-based autonomous surveillance system for older users, found that users themselves were *not* worried about privacy issues, and did not feel watched or monitored (2011). Any concerns around privacy were outweighed by the *benefits* of increased safety and security at home, the postponing of institutionalisation, and the enabling of ageing in place afforded by ambient intelligence technologies.

Some have argued that a meaningful balance needs to be struck between privacy, security and safety (Schulke et al, 2010). In their focus-group based research on the ethical aspects of using GPS technologies to track elderly people with dementia, Landau et al identified the need to *balance* patients' needs for safety, with the need to preserve their autonomy and privacy (2010). They found that professional caregivers, and families of patients, gave preference to patients' safety and protection, more than their autonomy and privacy. While concerns about the safety and security of intelligent environments are raised by many authors (Aarts, 2004; Nixon et al, 2004; van Hoof et al, 2007; Rashidi and Mihailidis, 2013) others recognise the need for trade-offs between privacy and security/safety requirements (Landau et al, 2010; Sharkey and Sharkey, 2012).

Following on from privacy concerns, a number of authors have highlighted various *data protection* issues around the storage, retention and disclosure of personal data, the access to, and secondary uses of, such data by key stakeholders and third parties, and the risks of accidental or intentional leaking of sensitive data (Price et al 2005; Sadri, 2011). Related issues have been raised around confidentiality, trust and informed consent by both Sliwa and Benoist (2011) and by Wright et al (2010). A major concern is whether the amount and detail of personal information requested in such systems is proportionate to their operational needs. The potential for sharing personal data *across* and between service sectors is considerably enhanced by the integration of systems across various domains, whereby homes are connected to hospitals (and to medical staff, nurses and therapists) to safety and social care services, and to daily life services (such as shopping, banking, and other public services) (Chan et al, 2009). In such scenarios, the information collected from environments by intelligent systems must be subject to relevant data protection laws and regulations (Hert et al 2009). In multi-user environments, systems also need to effectively distinguish between data for health monitoring purposes, data from carers, and users' personal data (Mittalstadt et al, 2013).

The fact that AmI systems are generally *distributed* systems in which multiple artificial and human agents collaborate and interact, has raises issues about delegation of control and decision-making, responsibility and accountability, and the blurring of human agency (Rouvroy, 2008; Aarts, 2004; Bohn et al, 2004; Brey, 2005). Questions have been raised about autonomous systems that have a life of their own and about the reliability of the technical infrastructure underpinning such systems (Cook et al, 2009; Bohn et al, 2004). As artefacts become more and more autonomous and make human intervention unnecessary, questions increasingly arise about who, or what, is ultimately in control of such systems, who is responsible if things go wrong and who is legally liable in such cases? (Langheinrich et al, 2004; Bohn et al, 2004).

The technologies that are deployed in intelligent environments are increasingly sophisticated and as such more difficult for users to fully understand. For some, the right place for computer technology is in the background, as a black box, helping and at the same time demanding little from the user (Weiser and Brown, 1996). This view is underpinned by the assumption that users do not need to know anything about the technological level. Others have argued that users *should* know how technology could affect their lives in various different ways both positive and negative (Augusto et al, 2011). If the objective of smart environments is invisible technology and natural interaction, then elements of those technologies should be made less invisible and less natural in order to answer users' concerns about privacy or security for example. These concerns are often overlooked (sometimes because they are not commercially convenient) but there are good reasons to assume that more transparency is in the best interests of *all* stakeholders in this area.

A related issue is the *transparency* of decision-making processes in such systems, and the extent to which implicit rules and choices, and embedded reasoning and classifications, are visible for inspection. According to Rouvroy, the pervasiveness and invisibility of data collection in AmI systems may have the effect of disappearing from human consciousness, and thus bypassing intentionality and control (Rouvroy, 2008). The fact that AmI landscapes are by definition embedded and unobtrusive could also make it difficult to detect and diagnose complicated faults in systems that are relatively invisible (Bohn et al, 2004).

The *social* implications of AAL systems have been explored by a number of authors, highlighting the potential risk for increasing, rather than alleviating, social isolation, and for reducing communication with the outside world in ways that can undermine users' existing social networks (Sun et al, 2009; Waterworth el, 2009). The potential to lead to stigmatisation amongst particular user groups, thereby undermining their dignity, is raised by Rashidi and Mihailidis (2013), Friedewald (2005) and Sun et al (2009) while Perry et al (2009) argue that initiatives such as telecare can lead to reduced staff involvement with people, and a loss of social contact. According to Chan et al smart home technologies have the potential to negatively affect human relationship and interactions, particularly where such technologies might replace personal interaction between users and care providers (2009). The potential loss of social interaction and human contact is also raised by Sharkey and Sharkey in relation to domestic use of robotic assistive technologies to support the elderly (2012). Coeckelbergh focuses on the replaceability issue in relation to care robots, namely whether the care provided by AAL technologies can replace human care (2010). A common objection to introducing such technologies into health care as replacements for human care is that, even if they are able to provide care, they cannot provide *good* care, since this necessarily requires engaging with human social and emotional needs.

Equality of access to technology is another key ethical issue that intersects with broader questions about the digital divide. Wright et al (2010) and Bohn et al (2004) question whether AmI technology will be universally and equally available to all potential users, or only to those who can afford them. Brown and Adams (2007) raise the possibility that unequal access to ubiquitous healthcare systems might serve to exacerbate existing inequities, whereby certain social groups are excluded from the benefits of AmI, while others are not.

All of the above issues have profound implications for the design and development of intelligent environments. Most design teams working within the field of AAL follow a user-led design methodology, particularly given that many potential users are from vulnerable groups, such as the elderly, frail, disabled and individuals with complex health and social care needs. According to Carroll, those who design and control these applications need to reflect on these considerations in the mediating functions of technologies, both in their development and implementation, especially where vulnerable populations are concerned (2009).

The incorporation of user perspectives into design and development is widely recognised as one of the foremost challenges in creating effective assistive technologies (Opwood et al, 2005; Dorrestijn, 2009; Oishi et al, 2010; van Hoof el al, 2011; Rashidi and Mihailidis, 2013). Projects have stressed the importance of incorporating users' needs into the building of pervasive home-care environments and AAL systems through requirements analysis, design and evaluation. Kaasinen et al propose a user-centric approach that analyses user acceptance and experience of interacting with intelligent environments, but also stresses the role of users in shaping intelligent environments, as potential co-crafters of their own DIY smart environments (2013). Hlauschek et al incorporated users' needs throughout the entire lifecycle of the *Living Lab* project for AAL, where multiple stakeholders were consulted on key issues such as privacy and data protection (2009). Despite these examples, inadequate comprehension of user needs and requirements is often identified as a major issue in the design and implementation of AAL and smart-home technologies. Questions have been raised about the usability of such systems, particularly in view of the often-cited technophobia and resistance to technology amongst older users. Questions have also been raised about the ways in which technologies are installed in homes, in terms of their location and appearance (Magnusson and Hanson, 2003). A key objective of AmI systems is to learn user profiles in order to respond to human needs, but Rouvroy argues that there is a risk that these needs will be defined by the systems themselves, and thus by the designers of those systems, with insufficient reference to their users (2008). For Chan et al the poor demand for smart home products, and the reticence about their adoption amongst potential users, reflects an industry that is supplier-dominated, and characterised by technology *push*, rather than demand *pull* approaches (2009). This raises questions about *whose* needs are being modelled and incorporated into such systems; the users? the care providers? the commissioners of such systems? or medical professionals? (Orpwood et al, 2005). These groups represent different stakeholders with quite different, and sometimes opposing, needs and interests.

From the preceding literature review the following ethical issues and principles can be identified which underpin the discussion of intelligent environments; privacy, data protection, security, transparency, autonomy, equality and dignity. In the following section we examine those articles from the literature surveyed which propose a framework for addressing these issues. The shortcomings of these various frameworks and the disparities between are then discussed.

3. Reviewing Ethical Frameworks in Intelligent Environments

Common sources of ethical frameworks in the area of intelligent environments are principles drawn from the field of medical ethics, in particular those proposed by Beauchamp and Childress (2001) as follows:-

- *Autonomy*; the ability of individuals to make choices.
- *Beneficence*; the principle of working for the benefit of the individual, for example, by meeting needs or reducing risks.
- *Non-maleficence*; the principle of doing no harm.
- *Justice;* the moral obligation to act on a fair adjudication between conflicting claims.

  (Beauchamp and Childress, 2001, p.12)

The above principles have been applied by various authors, including Perry et al (2009) and Schulke et al (2010). The ALADIN project, for example, presents ethical guidelines for the development, evaluation and use of AAL technologies (in this case, an adaptive lighting system for elderly residents) (Schulke et al, 2010). Schulke et al propose a hierarchy of ethical *principles*, as follows:-

1. Non-harm—that no harm shall be done to anyone using the technology.
2. Autonomy and self-determination—that technology should be used in accordance with the wishes, ambitions and values of users.
3. Welfare provision—that the technology should maximize possible advantages and minimize disadvantages, in order to improve the well-being and quality of life of users.
4. Equality (justice)—that the provision of technology resources should be fair, affordable, and available to all, irrespective of age, gender, disability, etc.

   (Schulke et al, 2010)

Brown and Adams describe a practice-based ethics approach in considering the ethical challenges of ubiquitous healthcare, specifically focussed around the issues of privacy, agency, equity and liability (2007). In the ACTION project, a European-wide project whose primary aim was to support frail older people and their carers in their own homes via the use of ICT, the project's overarching aims were founded on ethical concepts of autonomy, independence and quality of life (Magnusson and Hanson, 2003). Coeckelbergh (2010) argues that while privacy is *one* of the principles that should guide the design and use of AAL technologies, it should not be the *only* one, and needs to be balanced by healthcare principles, such as those outlined by Nussbaum (2006) including preservation, restoring, maintenance and enhancement of life, dignity, bodily health and bodily integrity.

Van Hoof et al propose that, for elderly users with dementia, technology should (i) not require any learning, (ii) look familiar, (iii) not remove control from the user, (iv) keep user interaction to a minimum, and (v) reassure the user (2007). Ikonen et al propose a framework of six principles in their project to design a mobile phone platform for AmI applications (2009). The project's approach was to use an advisory board of experts in ethical issues to provide a set of key principles. These principles were complemented with issues identified by user groups, and elicited through various interviews and focus groups. Six ethical guidelines were generated from this process that were used as a checklist throughout the design stage and before the commercial application development materialized. These guidelines were as follows:-

1. Privacy: an individual shall be able to control access to his/her personal information and to protect his/her own space.
2. Autonomy: an individual has the right to decide how and to what purposes (s)he is using technology.
3. Integrity and dignity: individuals shall be respected and technical solutions shall not violate their dignity as human beings.
4. Reliability: Technical solutions shall be sufficiently reliable for the purposes that they are being used for.
5. E-inclusion: Services should be accessible to all user groups despite their physical or mental deficiencies.
6. Benefit to society: Society shall make use of the technology so that it increases the quality of life and does not cause harm to anyone.

   (Ikonen et al, 2009)

Nixon at al propose a similar set of guidelines for preserving privacy in the design of smart environments (2004). These guidelines include the need to give *notice* to the user of the existence and activity of a smart environment by announcing in an open manner; to give the user a *choice* whether to engage/interact, and, if they do, to seek their *consent*; to provide mechanisms to hide or *anonymise* the identity of a user; to only distribute announcements of data or sensors to interested parties that match specific *rules*; and, finally, to ensure adequate *security* through the proportionate use of encryption in any given environment. These principles are combined with adherence to recognised data protection principles and information practices, including openness and transparency in record keeping, accessibility of records, limits to data collection, data accuracy, relevance, security and appropriate usage (Nixon et al, 2004). By following such guidelines, it is argued, many privacy decisions can be devolved to the user.

Callaghan et al categorise intelligent agents in terms of two underlying approaches; *end-user programming* (which empowers the user) and *autonomous-agent programming* (which reduces the cognitive load placed on the user, but involves less transparency) (2009). User-driven customization, they argue, supports creativity, increases control, and builds trust through greater understanding, while agent-driven customization reduces difficulty of use, but decreases control, creativity and trust. These factors shape the extent to which intelligent agents or people, are in control of both the functionality and topology of these systems, and the degree to which users are comfortable with the technology. As a result, these are important factors in the success or failure of these technologies. Callaghan argues that the less understanding of, and control over, their technological environment people have, the more resistant or fearful they will be of it. Similarly, Lim et al found that explanations clarifying a system's decision processes, and why it behaved in a certain way, resulted in increased user understanding and trust (2009).

Ball and Callaghan's research into users' views about intelligent environments suggests that maintaining control and autonomy are paramount concerns, in terms of users' freedom to make choices for themselves (Ball and Callaghan, 2011). Zaad and Allouch (2008) found that those elderly people who perceived having more control over a motion sensor system had a greater intention of using it, while Barkhuus and Dey (2003) warned that loss of control may result in user frustration and turning off services. Other issues of importance to users are the degree of adaptability, customisability and transparency of such systems. To address these concerns, Callaghan proposes a sliding scale or metaphorical volume control, for adjusting autonomy levels for each system in any environment. Adjustable autonomy enables the user to make agents back-off certain tasks and let the user take control whenever they so wish.

While there are many useful elements in these various frameworks, a comparison of the main ethical principles addressed by them in Table 1 reveals considerable disparity and unevenness in coverage of the major themes identified above. The table indicates which key ethical principles are considered (denoted by ✓) and which are not considered.

	Privacy	Data protection	Security	Transparency	Autonomy	Equality	Dignity	Non-harm	Beneficence
Brown and Adams (2007)	✓					✓			
Callaghan et al (2009) Ball and Callaghan (2011)				✓	✓				
Coeckelbergh (2010)	✓								✓
Ikonen et al (2009)	✓		✓		✓	✓	✓	✓	✓
Magnusson and Hanson (2003)					✓				✓
Nixon et al (2004)	✓	✓	✓	✓	✓				
Perry et al (2009)	✓				✓		✓	✓	✓

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Schulke et al (2010)					✓	✓		✓	✓
van Hoof et al (2007)		✓	✓		✓		✓		

Table 1. Comparing coverage of ethical principles in selected frameworks

While each of the frameworks discussed above have their respective merits, collectively they demonstrate three main problems. Firstly, they tend to be either philosophical or prescriptive at a conceptual level. Secondly, they tend to look at ethical issues in isolation from the practical process of designing and engineering actual systems. Lastly, they tend to assume a single primary user, whereas most systems, in reality, are likely to be implemented in *multi-user* environments.

With regards to the first problem, much of the discussion about the possible ethical and social implications of intelligent environments has been based around speculative projections about future dystopian scenarios of how these technologies might be implemented in everyday life. Wright et al for example, present four dark scenarios of AmI in the future that highlight its potential legal, social and ethical risks (2010). The dangers of making predictions about future trajectories of technology development in this field are exemplified by Ducatel et al (2001, pp. 4-7) who presented a future vision of AmI by 2010, a vision which plainly did not materialise.

Those frameworks which are informed by medical ethics are founded on laudable ethical principles such as non-maleficence and beneficence. While useful in establishing a *minimum* threshold of ethical practice, the problem remains of how to connect such general ethical guidelines to key application features—the second problem that we identified. While it is relatively easy to identify and enunciate ethical principles at an abstract level, it is less easy to concretise them. Such ethical guidelines need to be tangible, understandable and easy to follow by service and application designers, and by platform developers. To address the first problem we propose an alternative and more comprehensive framework that synthesises some of the best elements of existing frameworks, and combines these with principles drawn from our own experience of engineering systems in this area. We outline a methodology which enables ethics to be embedded in the core of any system. To address the third problem, we add considerations based on a user-centric approach which assumes a multi-user environment.

4. eFRIEND: Towards a more holistic ethical framework and methodology

The eFRIEND framework is informed by the *Intelligent Environments Manifesto* proposed by Augusto et al (2013a) which advocates the development of systems in a manner which is aligned with a number of explicitly defined priorities which are considered fundamental to empower users of intelligent environment systems. In particular we espouse the following principles articulated in this manifesto:-

- To deliver help according to the needs and preferences of those who are being helped
- To preserve the privacy of the user/s
- To prioritize safety of the user/s at all times
- To adhere to the principle that the user is in command and the computer obeys, and not vice versa (Augusto et al, 2013a)

We concur that the general principles of *non-maleficence* and *beneficence* should inform the entire development process of any system, and should establish a minimum threshold of ethical practice. We follow the customary understanding of non-maleficence, in this context, as the principle of not developing any system that will cause harm, especially to its intended primary users. Beneficence is similarly understood as the principle of working for the social benefit of users, by increasing their quality of life and, more broadly, for society generally.

Our approach is fundamentally *user-centred***,** whereby the views of key stakeholders should be a central consideration throughout all the stages of any project, and that any technology should be designed and implemented in accordance with the wishes, ambitions and values of its end users, who are the final intended beneficiaries.

We prioritise the need to identify and accommodate the preferences and requirements of *multiple user groups* in any number of different settings. These requirements may compete with one another, and may need to be accommodated and balanced by prioritising the preferences and needs of some users over others. Careful consideration is required of how ethical issues might be affected by multi-user environments where the requirements of each user may be different and may change dynamically. Potential user groups to be considered include:-

- *Primary users*, including individuals with complex social and health care needs and various impairments, from dementia and learning disabilities, to frail and elderly users. In some cases, the primary user may be a carer, family member or legal guardian if the main user has diminished capacity or competence.
- S*econdary users*, including carers, family members, social and healthcare professionals, and support workers, in a range of settings, from family homes, to residential care or sheltered accommodation.
- *Tertiary users*, including a broader range of social, healthcare and medical service providers, educational institutions, businesses, employers, and various other public and commercial service providers.

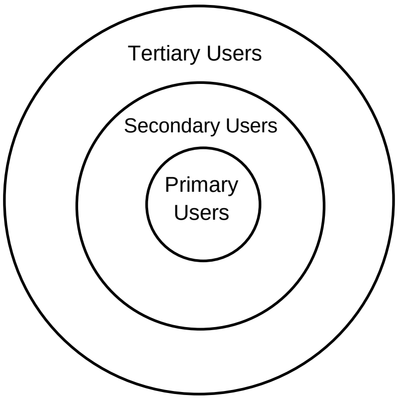

Fig 1. Potential user groups in a multi-user environment

In terms of the other core ethical principles, we argue that *privacy* settings and options need be taken into account, and designed into any system, from the very start of the development process. Crucially important is the users' ability to exercise control over monitoring, tracking and recording activities in intelligent environments, and over the information capture and dissemination capabilities of systems in such environments. We emphasise the importance of user ability to specify and adjust privacy levels for different services.

We regard the communication of privacy risks to potential users as a priority, as well the ability of both primary and secondary users to convey their own privacy requests and preferences. This is particularly pressing amongst vulnerable groups who may not necessarily be able to appreciate the privacy implications of disclosing personal information about themselves. We also regard the obtaining of informed consent for any data processing or monitoring as highly important, particularly for those with diminished cognitive, mental capacity. For environments with multiple intelligent devices, consideration is needed of the privacy implications of each device, or system feature, for *all* stakeholders in any given setting.

Personal information that is collected and processed from any intelligent environment must comply with relevant *data protection* legislation, both in principle and practice, as discussed above. Users should be able to determine the level of information sharing with secondary and tertiary users, and to specify what personal data can be accessed, and how it can be used and disclosed. This will involve seeking explicit consent for secondary uses by third parties. In multi-user environments this implies being able to effectively distinguish between personal data for purposes of health monitoring, social communication, or use of commercial services.

The incorporation of adequate and appropriate *security* measures into any system is key ethical responsibility, and an essential foundation of user trust and confidence in intelligent environments. This may involve ensuring the technical reliability of systems, or putting in place contingencies to pre-empt cascading of secondary effects that may result from potential system failures. It will also include the provision of safe online environments, particularly in mobile devices, and the adequate securing of personal data that is collected, processed and stored. At a more detailed level, this may include login and password requirements, contingencies in cases of loss or theft of devices, implementation of software upgrades and modifications, and choice of appropriate security measures. More generally, it will involve careful evaluation and weighing up of privacy-security trade-offs.

We recognise the importance of *autonomy* as a key principle and foundation of user trust. A key requirement of any system should be to provide its users with the ability to specify and adjust levels of autonomy, and to reconfigure, customize or override elements of intelligent systems by allowing users to take control.

In terms of *transparency*, it is important that potential users know how services can affect their lives in both positive and negative ways. This involves making relatively *invisible* processes more open and *visible*, such as system operations, background data collection and processing, or monitoring and surveillance activities. Users should be fully informed about systems, and should be provided with realistic descriptions, not only of the their capabilities, but also their weaknesses, limitations and potentially negative consequences.

The design and development of any intelligent environment system must take into account issues of *equality*, *dignity* and *inclusiveness* of provision. This involves ensuring the accessibility and affordability of devices, systems and services to primary user groups. It also involves designing systems and devices that do not attempt to substitute for human care, but augment, support and genuinely *assist* primary users. Social inclusion should be ensured through design, usability and accommodation of different levels of cognition, competence and technical ability amongst primary users. This should be done in ways that do not threaten or undermine the dignity of primary users, for example by stigmatising those with physical or mental impairments. These principles will need to be built into the technology, for example through interface design for various devices, or through physical installations in the home or other settings.

Table 2 below summarises the generic ethical principles outlined above, and suggests how these principles might be translated into practical steps and guidelines in the engineering process that are specific to different domains of application.

Generic Principles	Domain specific principles and practical guidelines
Non-Maleficence and Beneficence	• The system should avoid causing harm to any of the users • The system should proactively seek for opportunities to assist users • The system should actively benefit users by enhancing their welfare and quality of life
User-Centred	• Users should be placed at the centre of the development process • The type of technology and associated services should be agreed with users in advance • The system should be designed and implemented in accordance with users' wishes, ambitions and values • The systems should be customisable to dynamically evolving individual needs, preferences and requirements
Multiple User Groups	• The system should be aware of the different needs and preferences of all individuals in a multi-user environment • The system should consider how to balance the competing rights, preferences and requirements of different users
Privacy	• Users can specify privacy levels and preferences for different services • Users decide on, and can change, levels of acceptable recording, monitoring and tracking of activities
Data Protection	• Users have access to the sensitive information stored about them and can decide what can be done with this information • Users can determine levels of information-sharing and disclosure • The system should seek informed consent to secondary uses of personal data by 3rd parties • The system should adhere to recognised principles and good practices of data protection
Security	• The system should protect users and their information • The reliability and stability of systems must be ensured • The security of data transfer must be ensured • Adequate security measures and standards, appropriate to different environments, must be provided
Autonomy	• The system should support and enhance the independence and autonomy of its primary users • Users should have the freedom to override or "switch off" the system at any time if they find it unhelpful • Users should be trained to operate the system to the extent they wish • Users can determine for themselves degrees of protection, privacy and information-sharing
Transparency	• All users should be clearly informed of the pros and cons of the services offered by the system, including system capabilities, potential weaknesses, vulnerabilities and negative consequences • Users should be given notice of the existence of intelligent environment activity in an open manner • Background data processing, monitoring and surveillance should be made visible to users, where possible
Equality, Dignity and Inclusiveness	• The system should provide help regardless of age, technical background and ability • Affordability, fair provision, accessibility of technologies should be ensured • The system should accommodate different levels of cognition and competence • The system should reduce social isolation and not substitute for human care

Table 2. Translating generic ethical principles into domain-specific practical guidelines

As this section shows, a number of legitimate ethical concerns have been raised within this technological field and within the broad scientific community of intelligent environments. We have highlighted those which, in our practical experience, are more useful and relevant to this community. In any given project, however, it might not be feasible to satisfy every one of these principles in equal measure, but, we argue, developers should aim to satisfy as many of these as possible. In so doing, system designers and developers will need to assess important trade-offs between these principles, according to the circumstances of each specific project. These trade-offs will vary from project to project, and even between different users within the same project. We give some examples of such trade-offs in the next section. Clearly, different AmI applications will present different variations in the mix of ethical issues that they generate, requiring a different balance of principles. For example, an ambient intelligence system in a shopping mall will place a different emphasis on these principles, than one in the domain of Ambient Assisted Living (Augusto et al., 2012). The following section illustrates how the eFRIEND framework can be applied in an actual project, by showing how the principles and guidelines outlined in Table 2 can be translated into technical requirements that can be followed by development teams. The nature of this particular project raises some interesting questions around the balance between safety and privacy.

5. eFRIEND in practice: The POSEIDON Project

POSEIDON is an EC-funded FP7 project with partners from the UK, Germany and Norway, to develop intelligent, assistive technologies for people with Down`s Syndrome (DS) (POSEIDON, 2014). The project aims to create smart environments which can intelligently provide support to people with DS at different stages of their lives. The technological infrastructure for the POSEIDON system has three main components: 1) A virtual reality system based on a large screen TV, connected to a PC, to enable interaction between virtual characters, graphical representations and a user self-representation; 2) a mobile, tablet device making use of web services, easy-to-use applications and sensor data to provide personalized support for DS users; 3) an interactive table integrated into a typical living room, with various applications controlled by intuitive gestural interaction and sensing. The three components will be integrated. The static and mobile components are inter-networked enabling near real-time communication between them. These components are coordinated by intelligent software which turns the infrastructure into a context-aware intelligent environment which supports users anywhere and anytime. More specific details are provided in Augusto et al. (2013b).

The eFRIEND framework has been incorporated into the project deliverables, including the requirements analysis and the technical requirements for the prototype POSEIDON system which map onto the eFRIEND principles (Oesterreich et al, 2014). The mapping of eFRIEND principles to requirements began at an early stage of the project through ad-hoc discussions amongst the project partners, some by email, some during development workshops. This process continued through the prototyping stage. Three prototypes, of increasing sophistication, were assessed and checked against various key requirements. These included basic Framework Requirements [FR], Functional [Fun] and Non-functional [NF] requirements, and various Hardware [H] and Design [D] constraints. Some of the relevant requirements and constraints are noted below. The full list of technical requirements is published in Oesterreich et al (2014, pp. 257-265).

Non-Maleficence / Beneficence

POSEIDON aims to enhance the welfare and quality of life of its target users by enhancing their autonomy, independence and social inclusion. It incorporates measures to avoid any risk of harming the user. The project has an Ethics Advisory Committee, comprised of experts on ethics, data protection and on the target users (representatives of Down's Syndrome associations in the participating countries). POSEIDON is developed and evaluated in accordance with the Charter of Fundamental Rights of the European Union (ECFR) and the Convention on the Rights of People with Disabilities (CRPD).

Multiple Users

POSEIDON is specifically designed for a multi-user environment and incorporates the needs and requirements of various stakeholders, including primary users (people with DS), secondary users (parents / carers) and tertiary users (for example, personal assistants, support workers, specialist teachers, healthcare professionals, employers and local authorities). The project acknowledges that these requirements and preferences may need to be balanced and/or prioritized, and that they may change dynamically over time. Identifying modifications or changes, in response to evolving stakeholder views, is seen as on-going, iterative process that will continue throughout the life of the project, and beyond, into the maintenance stage.

User-Centricity

The POSEIDON project pursues a user-centric approach. It aims to develop assistive technology in joint collaboration with primary users and their carers at every stage of the development process. Primary and secondary users' wishes, values and needs are taken into account through detailed requirements gathering and analysis via surveys and face-to-face interviews with secondary and primary users. From this information, a clear understanding has been gained of primary users' living situations and daily living competencies, levels of proficiency using existing technology, together with the range of physical, sensory and cognitive difficulties they experience, including areas such as motor skills, speech, writing and learning disabilities. The POSEIDON system aims to address these challenges by providing context-specific help, information and intelligent assistance which is appropriate for different situations.

Reliability

Given that people with DS get frustrated easily, POSEIDON aims to avoid end-user challenges caused by difficulties in operation. It will allow, and compensate for errors, and provide adequate support, once live. Given that users may be dependent on the POSEIDON system outside the home, it must be robust, stable and reliable. System errors and crashes must be minimized, not least because these may provoke anxiety, and self-blame on the part of users.

Fr17—When live, framework components should have robustness and fault-tolerance comparable to non-vital commercial systems

NF11—The system should be available 24/7, except for short periods of downtime for maintenance such as system upgrades

NF12—When live, system should be reliable enough so that its services are working and available at least 95% of the time

NF13—When live, maintainability should be such that the time to get the system restored after major failure is less than 1 day

NF14—When live, technical support should be available

Fun6b—Should provide comprehensive outdoors navigation services

Safety and Security

The use of a tablet device in a public setting by vulnerable users raises potential safety issues. Location and context awareness features will help the user to tackle difficult situations where they feel insecure or unsafe. Interfaces should provide a quick and reliable communication channel in order to call someone for help. The tablet will include a panic button which, when touched once, will send a help message to the carer, and when touched twice, will open a phone line to the carer. Location-tracking via GPS and emergency connectivity were key requirements for carers. Through these features carers will have the option to know the current whereabouts of their protégés and their previous locations, and enable them to check that they had reached their destination safely. Primary users, for their part, will be able to contact the carer if they get lost or have problems finding their way and need help.

Fr5—When live, support the safety of the end users

Fun2—System should provide immediate access to phone call

Fun5—System should keep track of user's position when travelling outdoors

Fun27—Carers should have possibility to request location of primary user

Fun28—Carers should be able to contact the primary user

H9—Device level access security should be present

NF5—Network level security for mobile component

Privacy

The results of the requirements analysis confirm that privacy is of high importance to potential users of POSEIDON and must be guaranteed in usage outside the home. POSEIDON accordingly aims to ensure that no user's privacy is violated. Users and their carers will have the ability to adjust privacy levels and to specify which personal data can be accessed and for what purposes it can be used.

Fr6—When live, support the privacy of end-users. Provide optional user privacy settings to enable customization

Fun10—Users should be able to decide on, and vary, the level of privacy at a specific point in time

Data Protection

While the effective use of POSEIDON makes it necessary to collect and analyse personal data to provide appropriate tools for different situations, data protection principles will be adhered to regarding informed consent for data collection, security of data transfers, controlled access to secondary uses of personal data, and storage of (un)necessary data according to specified time limits.

Fr9—Safeguard user data at the server-side with appropriate backup. Optional user settings to customize data storage requirements

Fun12—When live, users' information security should be protected

NF10—Context-related data should be stored for no more than 6 months

Fun11—Users should be able to decide the type of information stored in the devices used

Social Inclusion

One of the most important requirements to emerge from survey data was the facilitation of communication and socializing with others, in order to reduce the risk of social isolation that people with DS face, and increase their independence. Social inclusion was in turn found to be closely related to mobility and travel independence, a major factor in feeling independent and less reliant on others. The ability to travel independently has a direct impact on the opportunity to build up and maintain friendships beyond school or work into leisure settings. Despite some variation in levels of travel independence, people with DS tend to rely on relatives for transport with only a minority using public transport, or walking, alone. Particular difficulties that were faced include using maps, reading bus timetables, dealing with unexpected events while travelling (such as delays or cancellations in public transport) and finding alternative or unfamiliar routes.

POSEIDON aims to reduce this travel insecurity by providing support for independent, safe travel. Potential areas of assistance include: customised multimedia-rich navigation systems based on GPS to negotiate public transport, real-time context-related information including timelines, video clips, photos, recorded messages with reminders, suggestions, signals and warnings and trip-planning assistance. POSEIDON provides support for communication through access to various customised communication tools and platforms. It aims to foster social inclusion by facilitating and augmenting inter-personal communication rather than replacing it. The integration of the three POSEIDON components, and access to the system by tertiary users (in education, for example) will enable it to support educational needs, such as lesson planning, homework preparation, target setting and behavioural issues. For those in work, assistive technology will help by facilitating time management, organizational skills and the learning of job roles.

Fun7—System should be proactive (instead of reactive) in the following situations: issuing reminders in the areas where the primary user has indicated more help is welcomed (candidates: planning trips, during travelling from A to B)

Fun15a—First User-level contexts to be considered are: travelling, communicating

Fun15b—Second User-level contexts to be considered are: studying, working, well-being

Fun16—When live, 'safety net' plan for foreseeable situations (e.g. bus does not arrive and no connection)

Fun18—System should provide support for further social integration at leisure time

Fun24—Include photos of faces for known people in the communication tools

Fun25—Organize photos collection for social interaction and sharing, and support for other functionality, e.g. notable landmarks while in transit to aid orientation

Fun29—Carers should have possibility to request emotional state of primary user for two-way reassurance that there are no problems and to ensure primary user feels supported

D5—Give priority to plans involving public transport

D6—Trip planners should focus on the next few steps and use familiar landmarks to guide

Autonomy

People with DS can perform many everyday tasks and competencies, but often only with help which reduces their independence and autonomy. One particular area of difficulty is *time management*, including understanding time intervals, time orientation, remembering and keeping appointments, processing large amounts of information at once, following and remembering complicated instructions. Other recurring challenges include handling new situations or changes in routine, managing diet and making healthy eating choices, and remembering to take medication. Another area of difficulty is *handling and managing money*, in particular, understanding the relative value of different amounts of money (which affects the ability to buy a product in a shop without help) and understanding the value of products when shopping. These difficulties are related to more general problems with numeracy and mental arithmetic, which in turn can affect confidence in going out with friends, and potentially further compounding social isolation.

The survey and interview data suggested a strong wish on the part of the target users to be more independent, and less reliant on carers and relatives. A high priority for POSEIDON, therefore, is to provide context-specific assistance to support autonomy and independence in the above areas. Enabling tasks to be completed independently without the need for assistance will potentially boost users' self-esteem and confidence. With this in mind, the kinds of assistive solutions POSEIDON will provide include portable timetables, prompts and reminders (whether for school/college, work or social events), step by step guides in performing daily tasks, and support in making healthier eating choices through reminders, visual lists or traffic light systems of healthy food options.

Autonomy, however, as previously discussed, also means users being able to control technology. POSEIDON will be adjustable to individual preferences and personal needs. Users will be able to customize the system, within their framework of capabilities or with the help of their carers. While default settings will be provided, POSEIDON will include the ability to override those defaults. The system will allow for some functions to be switched on or off, in line with different needs and competencies. Functions do not have to be used all the time, or in situations where support is *not* needed. It is recognised that too many choices and functions working at the same time could make it difficult for the user. Users, ultimately, will thus have the ability to scale back, or turn off the system if they feel bothered by it.
NF1—System should promote user's autonomy and independence
Fr8—Support for optional interface customization to suit the end-user's needs
Fun9—The system functionality should be customizable
Fun19—The system should assist with activities supporting independence and integration
D7—Special consideration given to the way time is represented and communicated
Fun15c—Third User-level contexts to be considered are: socializing, healthcare, managing money

Transparency

To be in the control of the system, users needs to understand its (re)actions, feedback and possible uses.

Potential weaknesses, limitations and vulnerabilities in the POSEIDON system will be made transparent to users, including system operations, data collection and use, and surveillance activities. An open source development environment will be created to attract the interest of different organisations, and enable compatibility with a wide range of applications and devices.
NF8—System should be open and transparent to users re: expected system functionality and weaknesses
Fr11—Documentation must be provided to enable project participants and third parties to develop POSEIDON components
Fr22—Extensible, allowing integration of new functionality not yet foreseen
Fun31—Provide confirmation that system has processed a request so user knows what is going on

Equality of access

POSEIDON upholds the principles of equality and fair access to technology. POSEIDON will be designed simply enough so that it can be used by the widest possible range of users with different potential levels of competence and cognitive ability. The system kits will be financially affordable and available in various price categories with different payment options. Accessibility and inclusiveness will also inform design and usability. In tune with user requirements, the system will avoid the need for fast reactions, fine motor skills and manual dexterity. It will be generally symbol-based, rather than text-based, using gestural interaction where appropriate. POSEIDON will have an attractive design and user interface that is fun and simple to operate.

Although DS is a well-known condition, it is still surrounded by negative preconceptions (Augusto et al, 2013b). The underestimation of the abilities of people with DS has an impact on their life chances and opportunities in areas such as employment. The POSEIDON project as a whole has the potential to counter this stigmatization and enhance the dignity of the primary user group. It can help to do this by shifting the image of people with DS away from attention on their deficits, to highlight and raise awareness of their strengths and abilities.
NF9—The system should provide help regardless of age and technical ability
H1—Cost of tablet should be less than €300
H2—Cost of virtual reality set less than €600
H3—Cost of adding interactivity to the table less than €300

NF17—Motivating to use
D2—Interface preferably based on symbol, icons and animations
D3—Take into consideration aesthetical features (colours, fonts, contrast, etc.)
D4—Consider design heuristics

It will be evident that some of the above requirements crossover more than one area and have an impact on several ethical principles simultaneously (context awareness, for example). What this does show, however, is that these principles can feed into, and map onto, concrete technical features and functions in any system. Having completed the requirements analysis, it is envisioned that this framework will permeate the remaining stages of POSEIDON's development. In the *design* phase, this will include the embedding of these ethical principles in the system architecture and functional specifications. This will be followed by their incorporation into formal methods, behavioural properties, and system agents in the *implementation* phase. Following the installation of the system, formal *verification* and *validation* of the system will ensure that its behaviour is consistent with the key ethical principles. In the *testing* phase, pre-pilot studies will be conducted so that the capabilities of the hardware and software used are fit for purpose and fulfil the requirements. This will be accompanied by usability testing with different prototypes, involving field trials and pilot tests from which detailed feedback will be gathered from users through a combination of workshops, diaries, reaction sheets and usage statistics.

As indicated in the previous section, the eFRIEND framework is best considered as an inventory of potential issues which designers should be aware of, and sensitive to. Addressing these issues in practice involves balancing different ethical concerns and making trade-offs between some of the principles. The POSEIDON project demonstrates some of the challenges of evaluating these trade-offs in domains where users have specific needs due to particular impairments or learning difficulties. For example, there has been a debate within the POSEIDON project about how much information secondary users should know about the primary user. Think of the following scenario: the user is being guided by the system to reach a destination (it could be work, college or a place to meet friends). The system detects the primary user is deviating from the expected route. Should the system contact a 'carer' (e.g., close relative) and warn the carer about the situation, and perhaps provide specific data about the whereabouts of the primary user? In some cases this may be advisable, in other cases the primary users do not want this to happen. In POSEIDON, it was agreed with the user representative organizations that the option of contacting a secondary user when a primary user is deviating from the route will be present in the platform, but that it can only be activated if both primary and secondary users give consent. For those cases where the primary users is an adult then he/she has to authorize explicitly the sharing of this private information, if the primary user is a minor, then the secondary user can decide.

This is an instance where privacy concerns about location monitoring and surveillance *do* need to be balanced against safety and security priorities, due to the vulnerability of some primary users. It is not a case of choosing between either privacy *or* security, but of carefully evaluating and balancing competing priorities, according to the particular needs of users and the design context, then proposing measures that are reasonable in relation to the potential risks at hand.

6. Conclusion

Intelligent environments are likely to be increasingly pervasive, and implemented in an ever wider range of contexts. They raise many ethical and social issues. Many of these issues have been acknowledged in the emerging literature in this field, but without necessarily proposing how to address these concerns from a practical or technical point of view. The frameworks that *have* been advanced have a number of shortcoming and limitations. This paper has proposed a more holistic user-centric framework that is guided by certain core ethical principles. It has shown how these ethical principles can be applied to specific domains, and, most importantly, how they can be translated into practical steps, rather than remaining at the theoretical or philosophical level.

The case of the POSEIDON project has been used to validate the eFRIEND framework by demonstrating how such a framework can be embedded in the development process and in the technical design of a specific system. The challenge remains to explore how this framework can be integrated into the software development processes of different methodologies, be they waterfall or agile approaches, iterative or incremental. This process, we have argued, is far from simple, given that some ethical principles may exist in tension with one another, and may require a careful evaluation of trade-offs (for example, increasing safety at the expense of giving up some privacy). It is important that these trade-offs are explicitly discussed and agreed with users so that any system reflects the users' preferences in such sensitive matters. There is no universal recipe for resolving such tradeoffs. The best that we can do is to make ourselves aware of the issues and hope to wisely and prudently balance them in answer to the needs of *specific* users in *particular* contexts. What this paper does demonstrate is that discussions at a conceptual level can be transformed into technical requirements and specifications, and that ethical principles can be embedded in such systems in practice, not just in theory. Arguably, such an approach has a greater chance of making a favourable impact on the real world, and delivering real benefits for the intended users of such systems.

References

Aarts, E. (2004) Ambient intelligence: a multimedia perspective, *IEEE Multimedia*, 11(1), 12-19.

Albrechtslund, A. (2007) House 2.0: Towards an Ethics for Surveillance in Intelligent Living and Working Environments. In: *Proceedings of the Seventh International Conference of Computer Ethics: Philosophical Enquiry* (pp. 7-16). San Diego, USA: University of San Diego.

Augusto, J.C., McCullagh, P.J., & Augusto-Walkden, J-A. (2011) Living without a safety net in an Intelligent Environment. *ICST Transactions on Ambient Systems*, 1(1), doi: 10.4108/trans.amsys.2011.e6

Augusto, J.C., Huch, M., Kameas, A., Maitland, J., McCullagh, P., Roberts, J., Sixsmith, A., & Wichert, R. (Eds.). (2012) *Handbook on Ambient Assisted Living - Technology for Healthcare, Rehabilitation and Well-being*. Volume 11 of the Ambient Intelligence and Smart Environments Book Series, IOS Press.

Augusto, J., Callaghan,V., Kameas, A., Cook, D., & Satoh, I. (2013a) Intelligent Environments: a manifesto. *Human-Centric Computing and Information Sciences*, 3(12) , doi: 10.1186/2192-1962-3-12.

Augusto, J., Grimstad, T., Wichert, R., Schulze, E., Braun, A., Rodevand, G.M., & Ridley, V. (2013b) Personalized Smart Environments to Increase Inclusion of People with Down's Syndrome. In: *Proceedings of the 4th International Joint Conference on Ambient Intelligence*, (pp 223-228). Springer International.

Barkhuus, L. & Dey, A. (2003) Is context-aware computing taking control away from the user? Three levels of interactivity examined. In: *Proceedings of UbiComp 2003, 5th International Conference*. (pp 149-156). Springer Verlag. DOI: 10.1007/978-3-540-39653-6_12

Ball, M., & Callaghan, V. (2011) Perceptions of Autonomy: A Survey of Users' Opinions Towards Autonomy in Intelligent Environments. In: *Proceedings of the 7th International Conference on Intelligent Environments* (pp. 277-284). Amsterdam: IOS Press. doi: 10.1109/IE.2011.68

Beauchamp T.L. & Childress J.F. (2001) *Principles of Biomedical Ethics.* Oxford: Oxford University Press.

Bohn, J., Coroama, V., Langheinrich, M., Mattern, F., & Rohs, M. (2004) Living in a World of Smart Everyday Objects—Social, Economic, and Ethical Implications. *Human and Ecological Risk Assessment*, 10(5), 763-785

Brey, P. (2005) Freedom and privacy in Ambient Intelligence. *Ethics and Information Technology*, 7(3), 157-166.

Brown, I., & Adams, A. (2007) Ethical Challenges of Ubiquitous Healthcare, *International Review of Information Ethics*, 8(12), 53-60

Callaghan, V., Clarke, G. & Chin, J. (2009) Some socio-technical aspects of intelligent buildings and pervasive computing research. *Intelligent Buildings International*, 1(1), 56-74.

Caire, P., Moawad, A., Efthymiou, V., Bikakis, A. and Le Traon, Y. (2014) Privacy Challenges in Ambient Intelligence Systems: Lessons Learned, Gaps and Perspectives. *Journal of Ambient Intelligence and Smart Environments*, 1, 1–23.

Carroll, J. M.(ed) (2009) *Context-Aware Mobile Computing: Affordances of Space, Social Awareness, and Social Influence*. San Rafael, USA: Morgan and Claypool.

Chan, M., Campo, E., Estève, D., & Fourniols, J-Y. (2009) Smart homes—Current features and future perspectives, *Maturitas*, 64, 90–97.

Coeckelbergh, M. (2010) Health Care, Capabilities, and AI Assistive Technologies, *Ethical Theory and Moral Practice*, 13(2), 181–190.

Cook, D., Augusto, J., & Jakkula, V. (2009) Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, 5, 277-298.

Coughlin, J.F., D'Ambrosio, L.A., Reimer, B., & Pratt, M.R. (2007) Older Adult Perceptions of Smart Home Technologies: Implications for Research, Policy & Market Innovations in Healthcare. In: *Proceedings of the 29th Annual International Conference of IEEE Engineering in Medicine and Biology Society* (pp.1810 – 1815) doi: 10.1109/IEMBS.2007.4352665

Dorrestijn, S. (2009) Design and Ethics of Product Impact on User Behavior and Use Practices. In: *Proceedings of the 5th International Conference on Intelligent Environments* (pp. 253-260). Amsterdram: IOS Press.

Ducatel, K., Bogdanowicz, M., Scapolo, F., Leijten J., & Burgelman, J-C. (2001) *Information Societies Technology Advisory Group (ISTAG): Scenarios for ambient intelligence in 2010*. Seville: Institute for Prospective Technology Studies/ European Commission. http://www.ist.hu/doctar/fp5/istagscenarios2010.pdf. (Accessed February 10th 2014).

Friedewald, M., Da Costa, O., Punie,Y., Alahuhta, P., & Heinonen, S. (2005) Perspectives of ambient intelligence in the home environment. *Telematics Informatics*, 22, 221–238.

Hert, P. D., Gutwirth, S., Moscibroda, A., Wright, D., & González Fuster, G. (2009) Legal Safeguards for Privacy and Data protection in ambient intelligence. *Personal and Ubiquitous Computing*, 13(6), 435–444.

Hlauschek, W., Panek, P., & Zagler, W. L. (2009) Involvement of elderly citizens as potential end users of assistive technologies in the Living Lab Schwechat. In: *Proceedings of the 2nd International Conference on Pervasive Technologies Related to Assistive Environments (PETRA 2009)*. New York: ACM. doi: 10.1145/1579114.1579169

Ikonen, V., Kaasinen, E., & Niemelaa, M. (2009) Defining Ethical Guidelines for Ambient Intelligence Applications on a Mobile Phone. In: *Proceedings of the 5th International Conference on Intelligent Environments* (pp. 261-268). Amsterdam: IOS Press.

Kaasinen, E., Kymäläinen, T., Niemelä, M., Olsson, T., Kanerva, M. and Ikonen, V. (2013) A User-Centric View of Intelligent Environments: User Expectations, User Experience and User Role in Building Intelligent Environments. *Computers*, 2, 1-33. doi:10.3390/computers2010001

Landau, R., Auslander, G. K., Werner, S., Shoval, N., & Heinik, J. (2010) Families' and Professional Caregivers' Views of Using Advanced Technology to Track People With Dementia. *Qualitative Health Research*, 20(3), 409-419

Langheinrich, M., Coroamă, V., Bohn, J., & Friedemann, M. (2004) Living in a Smart Environment – Implications for the Coming Ubiquitous Information Society. *Telecommunications Review*, 15 (1) 132-143

Langheinrich, M., Coroama, V., Bohn, J., & Rohs, M. (2002) As we may live – realworld implications of ubiquitous computing. *ETHZurich*. Available at: http://www.vs.inf.ethz.ch/publ/papers/langhein_aswemaylive_2002.pdf. (Accessed February 8th 2014).

Lim, B., Dey, A. & Avrahami, D. (2009) Why and why not explanations improve the intelligibility of context-aware intelligent systems. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2119-2128). ACM.

Magnusson, L., & Hanson, E.J. (2003) Ethical issues arising from a research, technology and development project to support frail older people and their family carers at home. *Health and Social Care in the Community*, 11(5) 431–439.

Mittelstadt, B., Fairweather, N. B., McBride, N., & Shaw, M. (2013). Privacy, Risk and Personal Health Monitoring. In: *Proceedings of ETHICOMP 2013: The Possibilities of Ethical ICT* (pp. 340-351). Odense: University of Southern Denmark.

Nussbaum, M. C. (2006) *Frontiers of justice: disability, nationality, species membership*. London: Harvard University Press.

Nixon, P., Wagealla,W., English, C., & Terzis, S. (2004) Security, Privacy and Trust Issues in Smart Environments. In Cook, D., & Das, S. (Eds), *Smart Environments: Technology, Protocols and Applications* (pp. 220-240). London: Wiley.

Oishi, M. M. K., Mitchell, I., & Machiel Van der Loos, H. F.M. (Eds) (2010) *Design and Use of Assistive Technology: Social, Technical, Ethical, and Economic Challenges*. New York: Springer.

Orpwood, R., Gibbs, C., Adlam, T., Faulkner, R,. & Meegahawatte, D. (2005) The design of smart homes for people with dementia—user-interface aspects. *Universal Access in the Information Society*, 4(2), 156–164

Perry, J., Beyer, S., & Holm, S. (2009) Assistive Technology, Telecare And People With Intellectual Disabilities: Ethical Considerations. *Journal of Medical Ethics*, 35, 81–86.

POSEIDON. (2014a). PersOnalized Smart Environments to increase Inclusion of people with DOwn's syndrome. Project information available at:- http://www.POSEIDON-project.org (Accessed May 21, 2014).

POSEIDON. (2014b). Deliverable D2.1: Requirements analysis, POSEIDON [FP7 ICT Call 10 STREP]. Unpublished technical report.

Price, B. A., Adam, K., & Nuseibeh, B.(2005) Keeping ubiquitous computing to yourself: a practical model for user control of privacy. *International Journal of Human-Computer Studies*, 63(1-2), 228–253.

Rashidi, P., & Mihailidis, A. (2013) A Survey on Ambient Assisted Living Tools for Older Adults, *IEEE Journal of Information Technology In Biomedicine*, 17(3), 579-590

Rouvroy, A. (2008) Privacy, data protection, and the unprecedented challenges of ambient intelligence. *Studies in Ethics, Law, Technology*. 2(1), 1-51

Sadri, F. (2011) Ambient Intelligence: A Survey, *ACM Computing Surveys*, 43(4), doi: 10.1145/1978802.1978815

Schülke, A., Plischke, H., & Kohls, N. (2010) Ambient Assistive Technologies (AAT): socio-technology as a powerful tool for facing the inevitable sociodemographic challenges? *Philosophy, Ethics, and Humanities in Medicine*, 5(8), doi: 10.1186/1747-5341-5-8

Sharkey, A., & Sharkey, N. (2012) Granny and the robots: Ethical issues in robot care for the elderly. *Ethics and Information Technology*, 14(1), 27-40.

Sliwa, J., & Benoist, E. (2011) Pervasive Computing - the Next Technical Revolution. In *Proceedings of the 4th International Conference on Developments in eSystems Engineering* (pp. 621-626). Los Alamitos, USA: IEEE Computer Society

Sun, H., De Florio,V., Gui, N., & Blondia, C. (2009) Promises and Challenges of Ambient Assisted Living Systems. In: *Proceedings of the Sixth International Conference on Information Technology: New Generations* (pp. 1201-1207). IEEE. doi: 10.1109/ITNG.2009.169

van Heerde, H.J.W., Anciaux, N.L.G., Feng, L., & Apers, P.M.G. (2006) Balancing smartness and privacy for ambient intelligence. In: *Proceedings of the 1st European conference on Smart Sensing and Context (EuroSSC)* (pp. 255—258). Lecture Notes in Computer Science 4272. Springer Verlag.

van Hoof, J., Kort, H.S.M., Markopoulos, P., & Soede, M. (2007) Ambient intelligence, ethics and privacy, *Gerontechnology*, 6(3), 155-163.

van Hoof, J., Kort, H.S.M., Ruttenb, P.G.S., & Duijnstee, M.S.H. (2011) Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users. *International Journal of Medical Informatics*, 80, 310–331.

Waterworth, J. A., Ballesteros, S., Peter,C., Bieber,G., Kreiner, A., Wiratanaya,A., Polymenakos, L., Wanche-Politis,S., Capobianco, M., Etxeberria, I., & Lundholm, L. (2009) Ageing in a Networked Society - Social Inclusion and Mental Stimulation. In: *Proceedings of the 2nd International Conference on Pervasive Technologies Related to Assistive Environments (PETRA 2009)*. New York, USA: ACM. doi:10.1145/1579114.1579160

Weiser, M., & Brown, J. (1996) Designing Calm Technology, *Powergrid Journal*, Version 1.01. Available at:- http://powergrid.com/1.01/calmtech.html (Accessed December 12th, 2014).

Wright, D., Gutwirth, S., Friedewald, M., Vildjiounaite, E., & Punie, Y. (Eds) (2010) *Safeguards in a World of Ambient Intelligence.* New York: Springer

Zaad, L., & Allouch, S.B. (2008) The influence of control on the acceptance of Ambient Intelligence by elderly people: an explorative study. In: *Proceedings of AmI European Conference 2008*, Nuremberg (pp. 58-74). Lecture Notes in Computer Science, 5355. Springer Verlag. DOI: 10.1007/978-3-540-89617-3_5