Intelligent Support Technologies for Older People: An Analysis of Characteristics and Roles

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Abstract For almost two decades, there have been many developments in using intelligent technologies to support older people, with many different terms proposed to describe these technologies including assistive robots, embodied conversational agents and relational agents. Many technologies have been proposed in many different configurations and many assistance roles have been explored. Characteristics of these technologies include tangible or virtual; anthropomorphic, biomorphic, creature or object-like; level of visual realism; paralinguistic abilities; interactivity; adaptability; movement and positioning. The assistive roles proposed include providing information, advice and reminders, helping with physical tasks, monitoring, providing companionship and emotional support. This paper provides an overview of the characteristics and roles of these technologies and attempts to clarify some of the terminology used. It aims to provide a guide for researchers from the wide range of disciplines working on such technologies for supporting older people.

1 Introduction

Intelligent support technologies (ISTs) is the term we have chosen to describe the many forms of technologically based assistance that have been proposed to support older people. The interest in intelligent support for older people has been driven by the growing need for such assistance as a consequence of demographic and societal changes. It is well known that the population throughout the world is ageing.

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The United Nations (UN) estimates that in 2015, there were 901 million people aged 60 or over (60 years is an inaccurate, but widely accepted threshold for old age; both 60 and 65 years are typically used as the threshold), by 2050 the UN estimates, there will be 2.1 billion older people. As a proportion of the population, that is a rise from 12 to 25%. Currently, Japan, Italy, Finland, France, Germany and Greece and some of the Baltic and East European countries have the highest proportions of older people (over 25% of the population in all cases), but by 2050 it is estimated that the 'oldest' countries will be Japan, Korea, Spain, Greece and Singapore (with over 40% of the population) (UN 2015). So it is not surprising that there is considerable research interest in Europe in this area, but also in Japan, Korea and Singapore. Along with this ageing population, the ratio of people of working age to older people (known as the Potential Support Ratio, PSR), important both in terms of those active in producing wealth and of those available to care for the older generations, is changing. Europe currently has an overall PSR of approximately four younger people for each older one, although many European countries have a PSR of less than 3.0. Japan currently has the lowest PSR in the world at 2.1. As the number of older people increases and the number of younger people decreases, these ratios will decrease and create a major societal issue concerning the availability of people to care for older members of society.

Technological support, in many forms, is widely seen as offering solutions to the growing lack of human power to care for older people. A particular feature of such technological support, beyond performing specific tasks, is that of providing social interaction and emotional support, to overcome the increasing social isolation and loneliness amongst older people. This may explicitly be the purpose of the technology, or it may be epiphenomenal to performing tasks, meaning it is a by-product of the task-based support. One way that much research has addressed the social interaction and emotional support issues, as well as those of the general acceptability of support technology by older people, is by creating technologies which have a tangible or virtual embodiment—whether that is as a humanoid robot, a animal-like robot, a digital pet or an avatar on a screen who converses with the older person. One reason for listing these examples is that there is such a variety of support technologies, and although they share many aims, they have a very wide variety of terminology to describe them. Even a term such as *embodiment* is problematic. There are very many definitions of embodiment (Ziemke 2001; Lee et al. 2006). Fong et al. (2003) use a cybernetics-derived definition: 'that which establishes a basis for structural coupling by creating the potential for mutual perturbation between system and environment' (p. 48). Other researchers, coming from a psychological or communications background, argue that embodiment is not about a relationship between technology and user, but a property of the technology, and whether it has a tangible or visible representation to encourage the user to think of it as a *sentient being* (Reeves and Nass 1996), which is the meaning of embodiment used by researchers in the area of *embodied conversational agents* (e.g. Cassell et al. 2000). This problem of terminology clearly arises from the fact that research on intelligent support technologies for older people is a highly interdisciplinary area of study, bringing together researchers from disciplines as diverse as artificial intelligence, computer science, cognitive science, communications, geriatrics, gerontology, human–computer interaction, psychology and robotics. Thus, there is a great need to explain terms across disciplines.

2 Terminology

Two terms on which there is good agreement are *robot* to refer to tangible technologies, that is objects in the real world, and *agent* to refer to virtual instantiations, often avatars on screens. However, there are many terms within these broad categories (Table 1 illustrates nearly 30 terms we have encountered in relation to technologies for older people), and often the functionality crosses over between terms. For example, Sabelli et al. (2011) evaluated a *conversational robot* which was a human-like physical object, but its functionality was actually identical to an *embodied conversational agent* as defined by Cassell et al. (2000). Even within a particular segment of the research area, there has been considerable fluidity in terminology. Breazeal (2002) coined the term *sociable robots*, but in a subsequent paper noted:

> Traditionally, the term "social robots" was applied to multi-robot systems where the dominant inspiration came from the collective behavior of insects … For this reason, the author coined the term "sociable" to distinguish an anthropomorphic style of human-robot interaction from this earlier insect-inspired work. The author has learned (after recent discussion with Terry Fong) that the term "social" has apparently changed over the years to become more strongly associated with anthropomorphic social behavior. Hence, we shall adopt this more modern use of the term "social" … but still distinguish "sociable" as a distinct subclass of social robots.

(Breazeal 2003, p. 168)

Thus, beyond these broad terms such as *robot* and *agent*, there are many terms used for ISTs and it may not be clear to new researchers what characteristics or roles they are attempting to distinguish. In the next section, we set out a classification of some of the key characteristics and roles that should be considered and discuss how these terms map onto those characteristics and roles.

But first, let us consider some of the commonly used terms listed in Table 1. *Service robots* are defined by ISO 8373:2012 as robots that 'perform useful tasks for humans' (ISO 2012). Fong et al. (2003) divided *service robots* into *assistive robots* which assist with physical tasks and *socially interactive robots* which interact with humans (but not necessarily assist them with tasks). Feil-Seifer and Matarić (2006) defined *socially assistive robots* (SARs) as the intersection of these two types of robots. The purpose of SARs is to assist humans, but to do this in a socially interactive way. The assistance might be by doing physical tasks but it might also be by providing information.

However, in another often cited definition, Broekens et al. (2009) use the terms *social robot* and *assistive social robot*. They distinguish these types of robots from

Table 1 Terms for intelligent support technologies (ISTs) for older people

Term	Used by
Affective communication robot	Khosla and Chu (2013)
Affective embodied agent	Tsiourti et al. (2014)
Assistive robot	Fong et al. (2003)
Assistive social robot	Broekens et al. (2009)
Assistive social agent	Heerink et al. (2010)
Conversational robot	Sabelli et al. (2011)
Companion robot	Broekens et al. (2009), Dautenhahn et al. (2007)
Conversational agent-based system	Ring et al. (2013)
Embodied conversational agent (ECA)	Cereghetti et al. (2015), Tsiourti et al. (2014, 2016)
Healthcare robot	Sabelli et al. (2011)
Listener agent	Sakai et al. (2012)
Relational agent	Bickmore et al. (2005)
Relational artefact	Turkle et al. (2006)
Robotic companion	Sidner et al. (2014)
Screen agent	Heerink et al. (2010)
Service (type) robot	Broekens et al. (2009), Pearce et al. (2012)
Sociable robot	Breazeal (2002)
Social agent	Lee et al. (2006), Heerink (2010)
Socially assistive robot (SAR)	Feil-Seifer and Matarić (2006), Johnson et al. (2014), Tapus et al. (2007)
Social embodied agent	Spiekeman et al. (2011)
Socially intelligent robot	Fong et al. (2003), Dautenhahn (2007)
Socially intelligent virtual agent	Tsiourti et al. (2016)
Socially interactive robot	Fong et al. (2003)
Social robot	Breazeal (2003), Fong et al. (2003), Bartneck and Forlizzi (2004), Lee et al. (2006), Broekens et al. (2009)
Virtual assistive companion	Tsiourti et al. (2014, 2016)
Virtual carer	Garner et al. (2016)
Virtual companion	Sidner et al. (2014)
Virtual (support) partner	Cereghetti et al. (2015)

service robots, which aid in physical tasks such as helping people to move around, and *companion robots*, such as PARO the robotic seal which was developed purely to imitate a real pet (Wada and Shibata 2007).

Researchers interested in *sociableness* of robots can search using the term SARs (Feil-Seifer and Matarić 2006; Tapus et al. 2007; Johnson et al. 2014), recognising that one of the main application areas for these has been for older people.

In addition, the search term *social robot* (Breazeal 2003; Lee et al. 2006; Broekens et al. 2009; Heerink et al. 2010) is still very current.

Turning to virtual ISTs, *embodied conversational agent* (ECA) is a term that has been inherited from earlier research for wider audiences (Cassell et al. 2000). These refer to screen-based computer-animated characters, usually human-like, which simulate a conversation with the user. ECAs were originally conceived to be easier to interact with than a graphical user interface, but as they have been developed in ISTs for older people, the social and emotional roles that these may play have come to the fore. Thus, Bickmore et al. (2005a, b) proposed the term *relational agent* to indicate ECAs that are designed to 'build and maintain long-term social-emotional relationships with users' (Bickmore et al. 2005b, p. 712). Other researchers have used terms such as *virtual partners* (Cereghetti et al. 2015) and *virtual assistive companions* (Tsiourti et al. 2014, 2016) for ECAs with very similar goals. Further terms are used to indicate different goals, such as *virtual carer* (Garner et al. 2016) to indicate caring and communicative goals and *listener agent* (Sakai et al. 2012) to indicate an ECA which can detect the cognitive status of older people with dementia.

This wide variety of terminology may be confusing for researchers when trying to understand the literature and does not clarify the important similarities and distinctions between different ISTs. Therefore, we have created a classification of both robot and virtual ISTs to try to highlight some of the important properties of these technologies.

3 A Classification of Intelligent Support Technologies (ISTs) for Older People

Although robots and agents seem very different as ISTs for older people, they share many characteristics and roles. A classification of these characteristics and roles is useful for research as the question being investigated is often what is the most acceptable, useful and usable form of IST for older people. Both when discussing particular studies and when comparing different studies, it is useful to have a clear picture of what characteristics and roles the technology has and what properties and roles have been manipulated.

We have found the following characteristics useful when considering ISTs. In each case, any IST will have a value on each of these characteristics, as illustrated in Fig. 1 (which does not show all possible combinations, it illustrates some combinations):

Tangible versus Virtual: As mentioned above, many ISTs are instantiated as tangible objects in the world (*Tangible*, terms in brackets refer to nodes in Fig. 1), usually termed *robots*, while others are *virtual agents* on a computer screen or *smart speakers* which are simply a voice (e.g. Siri or Alexa) (*Virtual*).

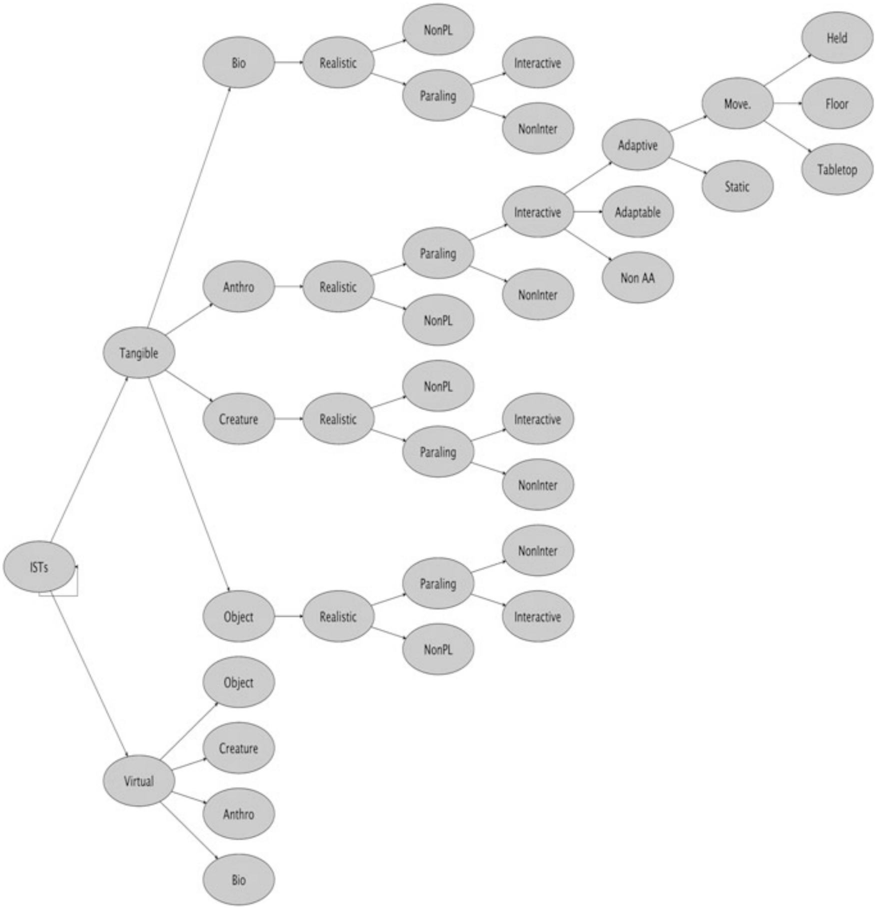

Fig. 1 Classification of characteristics of intelligent support technologies for older people

Type of Representation: Some ISTs attempt to be human-like (anthropomorphic, *Anthro*), some attempt to be animal-like (biomorphic, *Bio*), some represent new creatures which are not like any known animal (*Creature*) and some represent other non-biological real-world objects (*Object*). Many robots and agents are designed to look human and many robots look like animals (e.g. the seal-like PARO robot, Wada and Shibata 2007). Examples of 'new creatures' include the Reeti robot (www.reeti.fr), (Sidner et al. 2014) and ElliQ which is a featureless, moving 'head' (https://www.intuitionrobotics.com/elliq/). An example of a non-biological object is the IST investigated by Iwamura et al. (2011) who compared an anthropomorphic robot which carried a shopping basket to assist older shoppers in the supermarket with a robot which consisted simply of the shopping basket on a column. So the latter makes no attempt to look like any kind of human, animal or other creature.

Level of visual realism: For the anthropomorphic and biomorphic ISTs, the level of visual realism varies greatly. This is a deliberate strategy, presumably to deal with the problem of the 'uncanny valley' (Mori 2012). Some ISTs strive to create a very realistic representation, for example, the *virtual assistive companion* developed by Tsiourti et al (2014, 2016). Other ISTs use more cartoon-like or schematic representations, whether it is of a human (e.g. Bickmore et al. 2013 exercise coach for older people or Yasuda et al. 2013 cartoon-like grandchild for older people with dementia) or an animal. Clearly, this characteristic is a continuum from totally realistic to a cartoon, but for purposes of simplicity, in Fig. 1, we indicated a dichotomy (*Realistic* and *Cartoon*).

Paralinguistic behaviour including gestures: A further property related to realism is the extent to which ISTs use human or animal-like paralinguistic behaviour. This can include a number of visual and verbal behaviours such as making appropriate gestures when speaking, moving the eyes (if relevant) or other features appropriately and using realistic pitch changes (e.g. for questions) and tone of voice. Clearly, this characteristic could be broken down into a number of more specific categories, depending on the interest of researchers. Often it is hard to understand from research papers how much paralinguistic behaviour an IST is capable of. Tsiourti et al. (2016) mentioned that a set of facial expressions have been integrated into their *virtual assistive companion* and the Nao robot in the KSERA Project (Johnson et al. 2014) used a range of paralinguistic phenomena to attract the user's attention and make its recommendations more persuasive (in Fig. 1, we indicate simply *Paraling* or *NonPL*).

Interactivity: Most ISTs now aim to be interactive, that is accept input from the user and react to it appropriately. Some ISTs do this only in a limited way, and often it is not clear from research papers what the level of sophistication of the interaction is. For example, the evaluation of a robot by Sabelli et al. (2011), involved a Wizard-of-Oz-like implementation of interactivity, with a human operator using both pre-scripted and improvised interactions, but these appear to have been only single responses to questions and comments from older people (again in Fig. 1, we indicate simply *Interactive* or *NonInter*).

Adaptive and adaptable behaviour: The behaviour of the IST may be adaptive or adaptable. Adaptable technologies can be tailored by the user (or in the case of older users, a family member or carer) to suit the needs and personal preferences of the user. Adaptive technologies alter their behaviour by learning from the user's behaviour (van Velsen et al. 2007). For example, Bickmore et al. (2005b) virtual exercise coach used a simple process of adaptive behaviour in that the coach became more friendly the more times the user undertook exercises.

The final two properties are only applicable to the robot ISTs:

Movement: The IST may move around the environment. The classic idea of a robot is that it does move, but numerous studies have recently investigated robots which are static. For example, Brian (McColl et al. 2013) is a robot with just a head, torso and arms which sits in front of the user. Some IST robots also move in a manner to entertain, rather than to perform tasks. For example, Matilda can dance for users to entertain them (Khosla and Chu 2013).

Position: The robot ISTs can be floor-standing objects, which typically move around the environment, but not always; Sabelli et al. 's (2011) floor-standing robot was moved from place to place by human operators. Other robot ISTs sit on a table or other surface such as Matilda (Khosla and Chu 2013) or the iCAT (Herrink et al. 2010) standing 38 cm tall. Other robots, such the Nao, are not too tall to stand on a table at 58 cm, but can also be floor-standing. Finally, there are robots that are designed to be held, particularly robot pets, such as PARO (Wada and Shibata 2007).

Turning to roles, we make a distinction between social roles as used by Dautenhahn et al. (2005) such as that of a butler, and described using the sociological model of social roles (Huber et al. 2014) and task-based roles. The main task-based roles are as follows:

Providing information, advice and reminders: The iCat was programmed to initiate conversation, to set reminders, get directions to the supermarket and provide next day weather forecasts (Heerink et al. 2008); Karen (a virtual agent) and Reeti (a robot) were programmed to offer nutrition and health tips (both from Sidner et al. 2014).

Motivational support or coaching: For example, encouraging people to take physical exercise by a virtual agent (Bickmore et al. 2013) or robot (Fasola and Matarić 2012).

Monitoring: Working in cooperation with sensors in the environment, or worn on clothing, potentially risky behaviours can be detected, such as wandering or not drinking, and the agent, for instance the CareOBot (Sorrell and Draper 2014), can warn the older person.

Providing companionship and entertainment: Playing card games with Brian (McColl et al. 2013), and Bingo with Matilda (Khosla and Chu 2013), while Karen and Reeti offered short humorous anecdotes to the user (Sidner et al. 2014).

Providing emotional support: Interaction with PARO improved people's moods, making them more active and more communicative, both with each other and their caregivers (Moyle et al. 2017; Wada and Shibata 2007).

4 Conclusions

In studying robotic and virtual ISTs developed for older people, we were aware of the many questions regarding the nature of robots and virtual agents, and whether the latter can in fact be considered as robots. Other questions concern the tasks that these technologies are designed to carry out the style of interaction, and what are the technologies, or aspects of technologies, that make the interaction successful. The field has long been aware that it is difficult to draw meaningful distinctions between their characteristics and roles. In our paper, we expose some of problems that raise barriers to understanding, such as the proliferation of terminology and confusing distinctions. Our current contribution is to offer a conceptualisation with which to categorise and understand these technologies, that isolates characteristics and roles that are generic to both robotic and virtual agents. We believe that this contributes a working tool for thinking about these questions.

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