Perceptions of Autonomy

A Survey of User Opinions Towards Autonomy in Intelligent Environments

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Abstract—**In intelligent environment research, many believe that we should focus on developing end-user driven systems, seeking to empower the user; whereas, many others maintain that intelligent environments should be autonomous-agent driven, minimising user cognitive loading. We however, follow the premise that users of intelligent environments should be given a choice of how much autonomy they would like to keep and how much they wish to delegate to intelligent agents. This paper gives a brief overview of previous studies of user needs and concerns in intelligent environments and reports on a recent online survey that was conducted to assess people's opinions of the use of autonomy in intelligent environments. We aim to raise awareness of the issues with using static (and extreme) levels of autonomy amongst researchers of intelligent environments and pervasive computing systems.**

Keywords-intelligent environments; adjustable autonomy; pervasive computing; user-centric systems; itnelligent agents; autonomous agents; user survey

I. INTRODUCTION

The environments in which we work and live play a very important role in our lives; the world around us can have a heavy effect on our personal health and emotional state. Therefore, it is vital that intelligent environments and other pervasive computing technology be designed with personal and social factors in mind. User acceptance of pervasive technology has been shown to depend greatly on users' perceptions of privacy, which in turn has been linked to the degree of control users have [1-3]. Future pervasive computing systems run the risk of creating something comparable to Bentham's Panopticon [4] or some notion of 'Big Brother' being able to monitor our every move and know all of our personal interests, as in the famous book Nineteen Eighty-Four by George Orwell [5]. Over the years, literature has seen many authors warning of such dangers, for example [6-9]. Thus, many researchers in intelligent environments, and pervasive computing in general, take the stance that the user should be given complete control and hence adopt an end-user driven approach in their systems. With this approach, the user able to exercise direct control over the system and the system itself becomes more transparent to the user, which can work towards easing privacy and trust concerns for many users. Moreover, some researchers also believe that delegating tasks to autonomous agents can take away the sense of achievement from users, for example Ben Shneiderman was quoted as saying: "I think users want to have the feeling they did the job – not some magical agent" [10]. What's more, as we're told by Callaghan et al., an end-user driven approach to intelligent environment management can encourage creativity in users, it goes beyond the "current DIY approach of paint and wallpaper" and allows people to customise (or decorate) their homes in a digital sense [1].

Contrary to this, other researchers believe that due to the immense complexity and scale of intelligent environments and future pervasive computing systems, most average (non-technical) users might struggle greatly with interacting and managing with such systems; hence, equipping pervasive computing systems with intelligent agents is a necessity. Pattie Maes, one of the pioneers in the research area of software agents, tells us that agents will become ever more a necessity as computing systems become increasingly complex: "as computers are used for more tasks and become integrated with more services, users will need help dealing with the information and work overload" [11]. Pervasive computing systems are exactly the kind of thing that Maes is talking about here: they contain a myriad of services, devices and applications that all need to be managed. In his book, Ubiquitous Computing, Posland points out: "without autonomous systems, the sheer number and variety of tasks in an advanced technological society that require human interaction would overwhelm us and make system operation unimaginable" [12]. It is clear that agents can be advantages to users in management of intelligent environments and other pervasive computing systems. Callaghan et al. maintain that the use of artificial intelligence in such systems means much of the cognitive load that would be placed on the user could be off-loaded onto agents operating on the user's behalf [13].

This work however, follows the opinion that users should be given a choice as to how their intelligent environments are managed. While both the end-user driven and autonomous-agent driven approaches have great advantages, they are only suited to certain types of users [14, 15]. We postulate that by equipping intelligent environments with the extra dynamic of adjustable autonomy, we can allow users to find a optimal level, between the autonomous-agent and end-user driven management styles, at which they are most comfortable whatever their concerns – be fears of losing control, privacy concerns or low confidence in programming skills and ability

to manage pervasive technology. Adjustable autonomy can be described as maintaining "the system being governed at a sweet spot between convenience (i.e. being able to delegate every bit of an actor's work to the system) and comfort (i.e. the desire to not delegate to the system what it can't be trusted to perform adequately)" [16]. That is to say, adjustable autonomy allows an agent to 'back-off' and let the user take control of certain tasks that would usually be done autonomously, whenever the user so wishes. Using adjustable autonomy, previously fully autonomous systems can be made to 'share' their tasks with human users, so that they are completed as a team. In other areas of AI and robotics, researchers have successfully applied these concepts to enable human-agent teamwork in their systems, for example: Allen and Ferguson's human-machine collaborative planning system [17] allows humans and agents to work together to plan the evacuation of an island and researchers at NASA have developed a Mars rover that allows users to take control of specific sub-systems at any time whilst all others remain operating autonomously [18].

This paper discusses a selection of previous studies relating to user needs and concerns in intelligent environments and reports on a recent online survey that was conducted to assess people's opinions of the use of autonomy in intelligent environments. This work aims to raise awareness of the issues related to using static (and extreme) levels of autonomy amongst researchers of intelligent environments and pervasive computing systems.

II. RELATED WORK

Various studies of user requirements and concerns of intelligent environments have been undertaken in previous research; some of these research efforts are discussed below.

A study by Montano et al. at Göeburg University in Sweden conducted a number of interviews based on scenarios to try to gain a better understanding of people's concerns and requirements for smart homes [19]. Their main findings were that every-day users want support for tedious chores, such as house work, and greater security systems that a smart home might provide, although they are afraid to use complex systems. They found that a critical issue for users is control; in particular, users want to feel free in their homes to be able to execute their own ideas and be confident that everything operates in the way they expect it to. Another significant issue the authors found was that of privacy: users are worried about transmission and storage of their personal data externally.

The Amigo project was a cross-cultural study conducted across six different sites in five European countries [20]. In the project, Röcker et al. aimed to discover the requirements that potential users have in order to accept pervasive technology into their homes. Their findings concurred with Montano et al. They found that people's upmost concern is maintaining control and responsibility in their homes, and that people expressed fears of lack of privacy and security in a smart home. What's more, they also found that people worry that smart homes may encourage laziness and users may become dependent on the systems, and some had fears that intelligent systems may even come to replace interaction between people.

This study also identified some benefits that people think smart homes might entail, such as reducing information overload, preventing household accidents, automation of household chores, energy monitoring and saving, and making staying in touch with others easier.

A collaborative study was conducted in Korea and America by Samsung and the American Institutes for Research (AIR) [2]. Chung et al. explored the relationship between people and networked digital devices in their homes to gain an understanding of the future needs for intelligent environments. They found that users were worried about the compatibility of new and existing technology and people had a desire for technology to fit more harmoniously into their lives; specifically better user interfaces, communication methods and centralised entertainment resources were of high interest. Also users wanted to be able to customise technology in their homes. One important finding is that users' information needs change dramatically throughout the day: in the morning users needed the news, weather, and traffic information before leaving for work, and upon returning, they are more interested to know the status of the home.

The Morphome project was a three-year interdisciplinary study between the University of Tampere and the University of Art and Design Helsinki in Finland [3, 21]. They investigated people's opinions by introducing proactive technology (full-autonomous systems) into their homes. They aimed to answer the following questions such as "What things are people willing to delegate to proactive technology?" and "What kinds of technical and design issues ought to be taken into account when designing proactive technology?". They concluded that people were happy to delegate ambient services (e.g. lighting) and routine tasks (e.g. an alarm for waking up) to proactive technology, however, they wanted to keep control of more complicated tasks as they are not always so deterministic, for example the task of going to bed, unlike waking up, is not only dependent on time and commitments but it changes greatly from night to night, it also heavily depends on people's mood, what's on television, what they are doing and many other things. Mäyrä et al. found that, in general, many of the study participants took a disliking to the idea of proactive technologies, as they rely on guesswork and could cause more annoyance than benefit in more complex and critical tasks.

A commonality found in all of these studies is that the aspect of maintaining control is a paramount concern for potential users of intelligent environments. Additionally, the issues of adaptability, customisability and transparency of the system were also of great concern to many people as well as privacy of personal information and trust in the system. The studies also found that, in spite of their concerns, people could also see the potential benefits of intelligent environments and autonomous systems, such as the convenience of automating mundane tasks, enhanced security systems, monitoring energy usage, etc. These studies have each provided very useful contributions to research in intelligent environments and pervasive computing, and this work aims to build upon their findings by examining people's preferences towards varying levels of autonomy in intelligent environments. Some previous studies have touched on the subject of autonomy but do not

specifically examine multiple levels of autonomy; for example, the Morphome project, described previously, assessed people's attitudes towards only fully-autonomous systems, which they termed proactive technology, and did not take into account any types of semi-autonomous or end-user driven systems [3, 21]. The next section discusses a recent survey conducted to investigate people's opinions towards multiple levels of autonomy being used in intelligent environments.

III. AUTONOMY SURVEY

An online survey has been developed to gauge people's opinions of the usage of autonomy in smart homes and intelligent environments[1]. This section reports on a preliminary set of results obtained from the survey.

The focus of the survey questions revolved around how much autonomy people would prefer to be used in management of a smart home. By management we mean the creation of behaviour rules that describe the automation of services and devices in the environment. Along with the survey an animated video, shown in Figure 1, was produced to enable the survey participants to better understand the survey questions. The video explains the concepts of intelligent environments and intelligent agents, as well as four different management styles for intelligent environments:

1) Fully autonomous-agent driven: the agent monitors the environment, learns the user's behaviour and programs rules accordingly.

2) Semi-autonomous (high autonomy): the agent monitors the environment, learns the user's behaviour and generates rules accordingly but the rules can only become active in the system when they have been confirmed by the user. The user is presented with the opportunity to accept, reject or edit rules at the confirmation stage.

3) Semi-autonomous (low autonomy): the user programs the rules using a GUI, in which they build rules using a jigsaw puzzle metaphor. An agent can give suggestions for rules to aid the user.

4) Fully end-user driven: the user programs the rules using a GUI, in which they build rules using a jigsaw puzzle metaphor.

Over a period of three months, the survey received 159 responses in total. The survey was open to the all above the age of 16. Before the general release and advertisement of the survey, it was piloted tested on a small number of people from different age groups, backgrounds, technical abilities and some non-native English speakers. This was to ensure that the survey and video were easy to understand and complete. Also, in accordance with the normal practices of survey research, all questions in the survey (and the survey video) were carefully designed not to influence respondent's answers. The survey was advertised via email within the University of Essex, amongst various Google Groups mailing lists (including computer science related groups and general advertisement groups), and to personal contacts via email and Facebook.

[1] A copy of the survey questions and the survey video can be viewed at the following web address: http://privatewww.essex.ac.uk/~mhball/survey.html

A. Demographic Results

Figure 1. Screenshot of an animated video to explain the concepts in our online survey.

The initial survey questions were designed to attain some demographical information about the respondents. This subsection gives an overview of the results.

63% of respondents were male, 35% were female and 2% preferred not to say. 40% of respondents were aged 16-25, 28% were aged 26-35, 11% were aged 36-45, 8% were 46-55, 10% were 56-65, and 3% 66 and over. 70% of respondents hold either an Undergraduate or Postgraduate university qualification and 27% have achieved an A-Level, GCSE or other qualification, while 3% of respondents preferred not to say. The respondents had a wide range of occupations, such as: Student, Marketing Manager, Receptionist, Building Contractor, House-husband, and Trainee Teacher.

The majority of respondents were heavy computer uses, 70% reported that they use a personal computer (PC) either 31-40 hours or 41+ hours per week. 22% use a computer either 11-20 hours or 21-30 hours per week and only 8% use a computer 10 or less hours per week. 43% of respondents reported they have very little or no experience of computer programming whereas 56% of respondents reported they have some or a lot of computer programming experience, and 1% reported they were not sure. 78% of respondents had heard of a smart home or intelligent environment before taking part of the survey or watching the accompanying video, whereas 19% had not and 3% of respondents were not sure.

Being an online survey, based at a University, it is clear that the respondents will be biased towards educated users conversant with computers. However, we believe this demographic to be representative of a potential audience for the uptake of the type of pervasive computing technology involved: the majority are aged 16-35, regularly use computers, well educated and are from a variety of backgrounds and occupations.

B. Perceptions of Autonomy: Survey Findings

As mentioned previously, the main survey questions were designed to gauge people's opinions of how they view the usage of intelligent agents and autonomy in smart homes and

assess how they might like to manage a smart home if they were to occupy one.

Figure 2 shows the answers to the first set of questions, trying to determine how useful the survey respondents perceive the different styles of management to be. The respondents were asked to rate each style of management (described previously) on a five-point scale of: not useful at all, somewhat useful, undecided, useful or very useful. Respondents could also choose not to answer the question. The number of respondents who gave no answer has been omitted from the results. However, by way of providing some insight to this, for the questions regarding fully-autonomous style and both semi-autonomous styles, seven participants gave no answer and for the question about the fully end-user driven styles, nine participants gave no answer. As can be seen from figure 2, the majority for each of the management styles is either useful or very useful. The fully-end user driven style of management seems to be perceived as more useful, with over 80% of respondents saying they believe it would be useful or very useful. For both semi-autonomous management styles, around 70% of respondents said they believe them to be either useful or very useful; although the lower-autonomy style was the favoured of these with 38% of respondents selecting very useful compared to the higher-autonomy style with only 22% selecting very useful. The fully-autonomous management style seemed to be the least popular with around 60% of respondents saying they believe it to be useful or very useful. Also, only the fully autonomous management style has a significant number of people, 30%, who answered either not useful at all or somewhat useful. This perhaps indicates a low level of confidence in the ability of agents or even a fear/distrust of intelligent agents which may be a very significant finding for the intelligent environment and ambient intelligence research communities. Another interesting point is that for both the semi-autonomous management styles, around 10% of respondents were undecided as to their usefulness, whereas for

the fully-autonomous and fully end-user driven styles only 6% and 4% of respondents said they were undecided respectively. Without further evidence, we can only speculate on the reasons behind these results, which could be for example, unfamiliarity with interacting with intelligent system, not fully understanding the numerous technical issues involved, concerns of trust or even a more deep-seated psychological fears of systems that come close to offering capabilities we regard as the essence of being human, etc. Each of these would be in line with the findings of previous studies of user needs and concerns, as described in Section II, and also can be seen in the open-ended responses from the survey respondents in the later questions.

Figure 3 shows the results to the question: *If you were living in a smart home, how useful would you find the ability to change between the different styles of management, rather than always using the same style of management?* Seven of the survey participants did not give an answer for this question, which has been omitted from the results forming the results. As you can see, the vast majority of respondents think that the ability to change between the different styles of management (i.e. the ability to adjust the level of autonomy at different times) is either useful or very useful and none of the respondents said they think it is not useful at all. The respondents were also encouraged to give a reason for their answer. Some of these include: "very useful - *different tasks require different styles of management*"; "very useful - *It is quite sensible to take the control sometimes while some important decisions will be made, or for a supervisory session while teaching the agent how to act according to a specific situation*"; "useful - *Flexibility to cope with changing circumstances*". The results discussed above support the need for an adjustable autonomy based solution to intelligent environment management. They indicate that, while the survey respondents, as potential users of intelligent environments, may prefer the concepts of end-user driven management styles, they also have some interest in the semi-autonomous and fully-
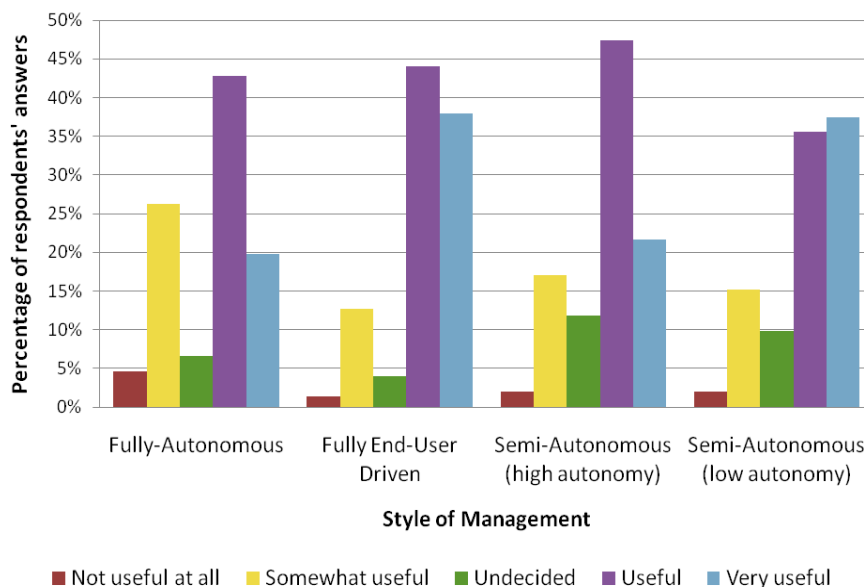

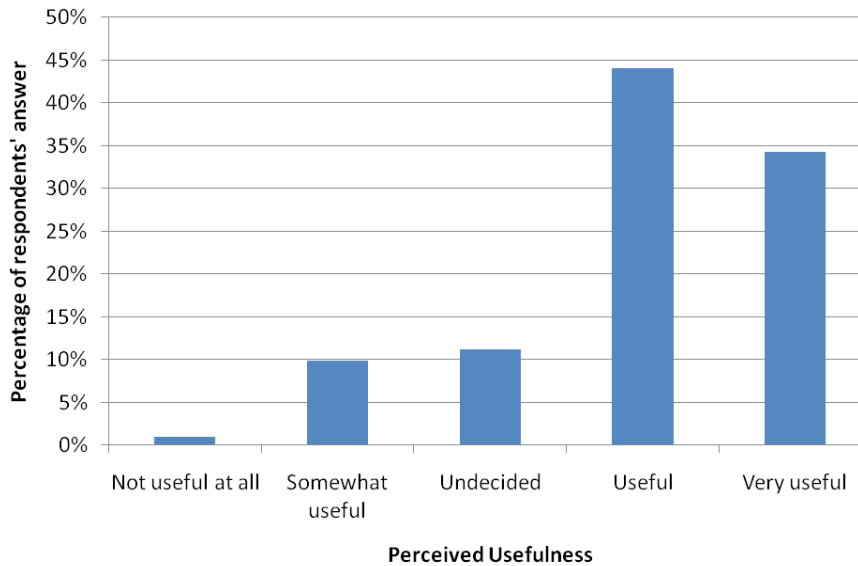Figure 2. Graph showing perceived usefulness of the different management styles.

Figure 3. Graph showing usefulness of ability to change between the different management styles.

autonomous solutions. What's more, we can clearly see that the survey respondents deem the ability to change between the management styles described (i.e. to adjust the autonomy level) would be a highly useful in an intelligent environment. In the reasons the respondents gave for their answers we can see an interesting trend: while many stated that they simply desired the extra flexibility, many others expressed concerns over trusting an agent and wished to build confidence in the intelligent agents before giving them too much autonomy.

In the next set of questions, the respondents were asked to think about a number of different sub-systems in a smart home and decide how they would like them to be managed (which style of management). The different sub-systems were:

- Lighting systems (e.g. automatic room lighting)

- Heating systems (e.g. automatic indoor heating)

- Entertainment and media systems (e.g. recording favourite TV shows, finding news stories, music or movies that might be interesting to you)

- Security systems (e.g. automatically closing and locking doors and windows when the home is unoccupied)

- Environmental services (e.g. monitoring and regulating energy usage within the home)

In each question, the participants were asked to consider how they would like one sub-system to be controlled. Table 1 shows the answers attained from these questions and Figure 4 shows the popularity of each answer (each style of management) over all the questions in this set. In each of these questions, seven respondents gave no answer. Again these non-responses have been omitted from the results. As can be seen from Figure 4, in general terms, the two semi-autonomous management styles were most popular, with the higher level of autonomy being preferred, and the fully autonomous management proved more popular than the fully end-user

driven management. This provides an interesting contrast to the results from the previous questions, which indicate that people perceive the less-autonomous management styles as more useful, with the fully end-user option proving most popular; however, in these results, when people were asked to think more in depth about what will actually be managed in the intelligent environment, they seem to prefer a higher level of autonomy, with the fully end-user option proving to be least popular. Whilst there were some paradoxes in these results, there were some strikingly consistent findings, for example, heating, which is already semi-automated in most homes, retained this user-preference. On the other hand, entertainment, which is connected to deep-rooted internal values and tastes, was a clear winner. As before, without further evidence we can only speculate on the reasons; however, based on the open-ended comments made by the respondents and findings from previous user studies (describes in Section II), one cause to this flip in opinion could the survey participants' unfamiliarity with the technology meaning that task of managing such a complex system might seem daunting for an average computer user. So initially people may prefer the help of an agent to manage the intelligent environment, but over time, as people because most accustomed to the technology, they may refer back to their previous opinion that using a fully end-user driven style of management is better for them.

Another striking, and important finding, is that people have very different autonomy needs for differing types of sub-system and the different ways people view them. As can be seen in Table 1, the responses for lighting, heating and environmental sub-systems were quite similar with the semi-autonomous management styles being preferred and the higher autonomy option being favoured; whereas, the responses for the entertainment sub-systems tended more towards fully-end user driven management and semi-autonomous management with low autonomy, and for the security sub-system the results were more evenly distributed between the two semi-autonomous styles and the fully-autonomous style (with a slight preference towards the semi-autonomous style with high
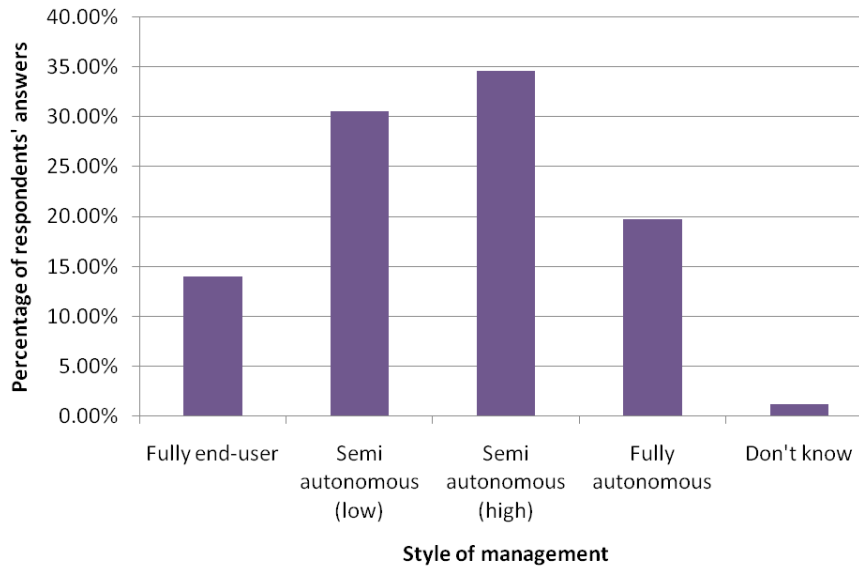
Figure 4. Graph showing the overall popularity of the different management styles for the specified systems.

autonomy). A possible explanation for this is, for example, lighting, heating and environmental systems could be viewed as non-critical systems (i.e. it doesn't matter too much if they fail) and hence users feel if they were managed (more) autonomously by agents the potential benefit (of increased convenience) to the user outweighs the potential risk factor of handing over control to intelligent agents. However, as discussed earlier, an entertainment sub-system could be seen as highly personal to the user (connected to deep-rooted internal values and tastes) and something for which the user's preferences could often change depending on mood, time of day, current activity or any number of factors; hence, it could be the case that the survey respondents don't have confidence in the ability of the agent to learn such preferences from simple environment sensors (due to their complexity and inaccessibility) and so they believe that the risk of the agent making mistakes, and perhaps causing the user annoyance, outweighs the potential convenience gained by agents managing the sub-system. Put another way, one could argue the question - what is the sense in trying to make an agent learn something it can only partly know and thus make bad guesses at, when that knowledge is known with certainty within the user and can be better extracted by other means, i.e. the user having control? The responses for the security sub-system were a bit more mixed than for the other sub-systems, with the higher autonomy options being slightly favoured. It may be the case that higher autonomy is favoured here because people are

already quite familiar to electronic security systems, and automated monitoring (in contrast to autonomous agent management) is seen as an in keeping with how their system already operate and which they trust.. On the other hand, a number of people may prefer a management style (in terms of setting up and maintaining the system) in which they have more control, as they see security of their homes as something very critical and wouldn't like the idea of trusting to an intelligent agent. Thus, the answers may be dependent on the differing understanding and interpretations of the respondents.

From these results, in general terms, we can see that people prefer the semi- or fully-autonomous management styles for sub-systems that are not connected to style or taste (e.g. heating), but for systems that are (e.g. entertainment) they prefer end-user or semi-autonomous (low) management. This further justifies the need for adjustable autonomy in intelligent environment management, as there is no single (fixed-autonomy) solution that would be ideal for all users for all parts of their intelligent environment systems. This point is emphasised in the final question of the survey. The survey respondents were asked: *If you were living in a smart home, how useful would you find the ability to choose the style of management for individual parts of the system, rather than one setting for the entire system?* Figure 5 shows the responses to this question. In this question, thirteen respondents gave no answer. Again these non-responses have been omitted from the

TABLE 1. HOW RESPONDENTS WOULD PREFER EACH OF THE SUB-SYSTEMS TO BE MANAGED.

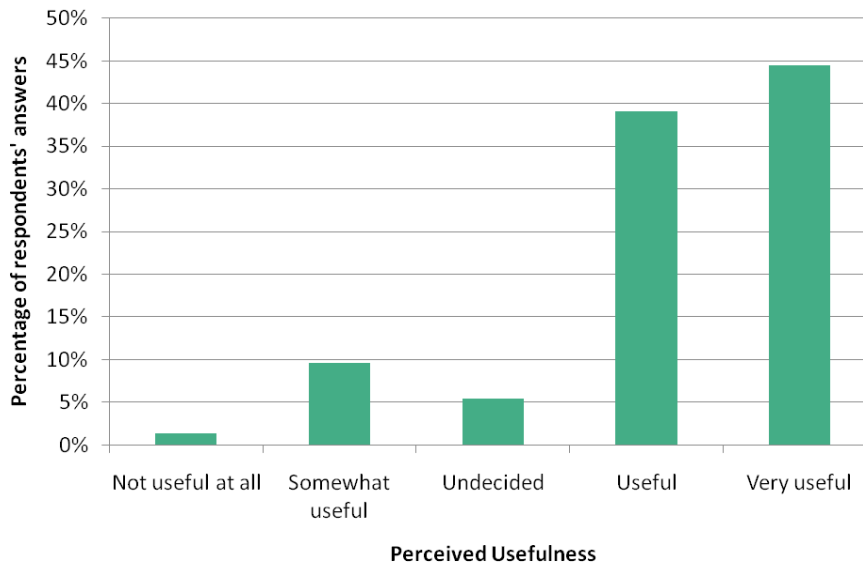| Sub-system	Answer / Percentage of respondents answers				
	Fully end-user	*Semi-autonomous (low)*	*Semi-autonomous (high)*	*Fully-autonomous*	*Don't know*
Lighting	12.50%	28.95%	36.18%	20.39%	1.97%
Heating	13.16%	29.61%	39.47%	16.45%	1.32%
Entertainment	27.63%	36.84%	25.00%	10.53%	0.00%
Security	13.16%	28.95%	32.89%	23.68%	1.32%
Environmental	3.29%	28.29%	39.47%	27.63%	1.32%

Figure 5. Graph showing the usefulness of being able to choose the style of management for individual parts of the system.

results. As you can see from the graph, very few respondents thought that this ability (adjustable autonomy for individual part of the intelligent environment) was not useful as all and the vast majority (over 80%) said they would find it either useful or very useful. Again, the survey respondents were asked to give a reason for their answer. Whilst these answers give a qualitative (and individual) rather than quantitative insight, they do provide a useful feel for what some respondents thought .For example, some examples were: "very useful - *As I got used to a smart home I might have more confidence in some things being managed by an intelligent agent before others.*"; "very useful - *There are some things that I'd be happier to monitor myself (security) as a glitch in the system would be very detrimental. There are others that I'd be happy to let run without me having to do anything like the lights*"; "useful - *I'm moody and would like the choice of choosing different management styles as I'd like to have more control over certain things*".

The results from the final question confirm our findings from the previous results. They show that a large percentage of respondents would like the ability to adjust autonomy of individual sub-systems in their intelligent environment. What's more, from the reason people gave for their answers we gain an interesting insight into people's perceptions of intelligent environments. Many people expressed concerns over privacy of certain sub-systems or did not believe in the ability of an intelligent agent to find effective behaviour rules for the more personal sub-systems. Moreover, others expressed a lack of confidence in their own ability to manage the intelligent environment and said they would dial-down the level of autonomy as their confidence increases.

C. Results Discussion

In this survey we have asked a large number of potential intelligent environments users their opinions on autonomy in intelligent environments. From these results, the usefulness for an adjustable autonomy management system for intelligent environments is clear. We can see that different people prefer different styles of management with different levels of autonomy and many people would not always like to use the same static level of autonomy for all sub-parts of the intelligent environment system. For example, we see in the results that people would prefer to maintain a higher level of control (lower level of agent autonomy) for a more personal system such as entertainment and media services; whereas for other sub-systems, such as heating and lighting, people don't mind giving up a certain amount of control in exchange for increases convenience (a higher level of agent autonomy). Additionally, some people feel that, with such a complex system, they would initially prefer a higher level of autonomy, with an intelligent agent taking a role in helping to manage the system, and decrease the autonomy level overtime as they become more accustomed to the technology. We speculate that a person's views may also change over their life, as previous research have reported that older, or medially infirmed people, are comfortable to give up control as their physical or cognitive ability degrades. Whilst the focus of this survey is different to earlier surveys, as described in Section II, its results broadly align with them in reporting that people cite control over the system as being their most important concern, and also trust being another issue raised repeatedly throughout the survey.

Furthermore, these findings reveal the value of an adjustable autonomy system, not only for use in real-life applications, but also as a design tool. In the first set of questions, the survey participants showed a preference towards the fully end-user driven management style; whereas in the second set, when people were asked to think about managing the individual sub-systems in the intelligent environment, the fully-end user driven management style was the least popular and the semi-autonomous (with high autonomy) was the favourite. This change in preference here indicates the instability of people's opinions about pervasive technology and in fact their opinions could easily change again once they have experienced a real intelligent environment. Hence, there is a real need to build an adjustable autonomy test-bed to gauge people's opinions in this case also.

As well as guiding our own research, we hope that the results to this survey will raise awareness of the issues of extreme and static levels of autonomy amongst other researchers of intelligent environments and pervasive computing technology. When designing and developing systems in these very user-centric areas, we would urge researchers to experiment not only with different user interfaces but also with different levels of autonomy. Given the huge difference between the nature of pervasive computing systems and more traditional desktop computing paradigms, researchers may find that users express unexpected concerns over either their own responsibilities in controlling the system or over allowing autonomous/intelligent agents to operate in the system. Researchers may even find that given the diverse nature of people, their final systems may have to employ an adjustable autonomy mechanism to be acceptable to wide user base.

Whilst we hope these results provide a valuable insight to people's attitudes towards autonomous agents, it is clear that there is need for further work in this area. This not only opens up opportunities for computer scientists researching and developing pervasive computing systems, but also provides opportunities for researchers of sociology and psychology to explore the underlying reasons for the user attitudes expressed in these findings.

Finally, to further this work and build upon these findings, we are currently implementing an adjustable autonomy test-bed, described elsewhere [14, 15].

IV.   CONCLUDING DISCUSSION

There is a long-standing debate over the role that intelligent agents should play and how much autonomy they should be given in user-centric systems such as intelligent environments and other pervasive computing technologies. In this paper we discussed previous studies of user needs and concerns relating to intelligent environments and have reported on a recent online survey conducted to gauge people's opinions on the use of autonomy in intelligent environments. The results strongly indicate that different people would prefer different levels of autonomy in different situations and different levels of autonomy for different sub-systems of an intelligent environment; hence, there is a strong requirement for employing adjustable autonomy in intelligent environments. This paper aims to spread awareness, amongst researchers of intelligent environments and pervasive computing, about the issues they may with regards to autonomy in their research and we encourage other researchers to also consider using adjustable autonomy in their own intelligent environment systems.

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