L. Stapleton, Duffy, D., Jordanova, M., Lakov, D. & Lyng, M. (2004). 'Revising the theory of socially inclusive systems engineering: Social impact considerations in distributed assistive systems for the learning disabled', in Kopacek, P. (ed.), *Proceedings of the International Multitrack Conference of Advances in Control Systems,* Elsevier: North Holland, forthcoming.

REVISING THE THEORY OF SOCIALLY INCLUSIVE SYSTEMS ENGINEERING

SOCIAL IMPACT CONSIDERATIONS IN DISTRIBUTED ASSISTIVE SYSTEMS FOR THE LEARNING DISABLED

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Abstract: the relationship between humans and advanced technology can be viewed as a network of interests of technical and non-technical agents. Drawing upon instrumental realist approaches as set out in agent network theory the paper describes a project currently underway in Ireland and Bulgaria which delivers comprehensive, assistive *systems* for people with learning disabilities. These systems address many of the difficulties associated with current assistive technology (AT) programmes, problems typically associated with the narrow focus of AT upon technology solutions. Whilst limited, it delivers a sound ethical basis for technology-centred programmes, and new trajectories for engineering research.

Keywords: social impact of automation, assistive technology, ICT, artificial intelligence, ethics.

1. INTRODUCTION

Current theories of systems engineering often adopt a 'one solution fits all' approach (Siddiqi (1994), Stapleton & Murphy (2002)). Consequently, many engineering methodologies do not take sufficient account of local context issues, and especially ignore the difficulties that socially marginalized people face in working in contemporary organisations. The functional rationalism that underpins the one-solution-fits-all paradigm has recently come under significant pressure from systems and engineering theorists who argue that it is far too unsophisticated for the kinds of complex organisational and social information spaces that are now so common in both business and education (Stapleton (2001), Clarke & Lehaney (2000)). This functionally rationalistic approach reflects a scientific rationalism which has often excluded the marginalized from the centre of scientific discourse. Consequently, we have mobile phones that the elderly or visually impaired find difficult to use and large scale information systems which traumatise their user community (Stapleton (2003), (2002)).

2. HUMAN-TECHNOLOGY HYBRID SYSTEMS

In this paper the systems design process is seen as the folding together of humans and technology into a single, coherent system. Adapting Latour's instrumental realist approach yields a model which illustrates how such a folding process might work. Latour argues that the twin mistake of functionally rationalism, on the one hand, and sociological approaches on the other, is that they both try to understand the relationship between humans and non-humans is their focus upon essences (artefact or human). In Latour, both are transformed into something new, as illustrated in figure 1. This illustrates to the software engineer and the information technologist one way in which social impact is created. The technology is no longer an essential thing, nor is the human. It is *both together* i.e. Human and artefact are folded into each other. They are transformed into something new, a composite of social and artefact (e.g. Ihde (1998)).

This shifts attention away from 'technology' or 'society' or 'social context' to a new combination of social and technological: the 'hybrid system'. Once we do this, we can see that goals (or functions) change from those of the individual components (human and non-human) to the goals/functions of the hybrid actor. This is a very important philosophical step in our base assumptions. In systems engineering we must now focus upon a whole new array of actors and actions – the hybrid systems and their functions. This opens a new research trajectory for the social impact of technological artefacts. We notice that we are now dealing with, not the goals of humans or technologies, but the new, distributed, mediated and nested set of practices whose sum may be possible 'to add up' but only if we respect the importance of mediation (*interference*) in the relationship.

As this process of *interference* and *folding* develops we note how the original (perhaps explicit) goals can be lost in a maze of new goals as the entire system becomes more and more complex. For example, an early human discovers the stick, and we have a stick-human hybrid. Perhaps the human initially uses this stick to plough the ground. However, the human becomes frustrated with the stick and sharpens it thus creating a whole new set of goals and functions, such as the stick as a defensive or offensive weapon. This whole new set of goals or functions could not have been foreseen at the outset when the stick was originally discovered and deployed. It illustrates how technology deployment must recognise that, as humans enter into and develop new relationships with the technology, goals and functions shift. This rationale directly implies that researchers of social impact must now introduce learning and adaptation theory into their armoury. Simultaneously, they emphasise design and re-design principles for the technical component. We have not been 'made by our tools' as indicated by Marx and Hegel (homo faber fabricatus). Rather the 'association of actants' is the important thing for the researcher of social impact associated with IT deployment.

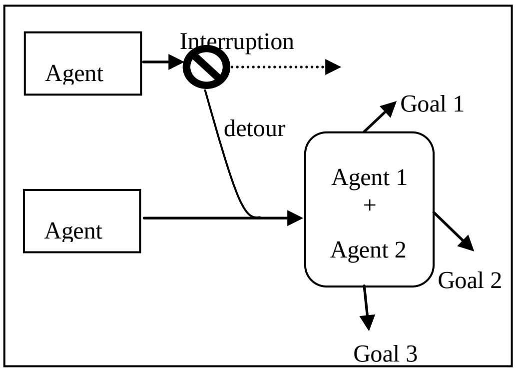

Figure 1. Interference & Goal/Function Transition (adapted from Latour (1999))

By implication systems engineering researchers must understand how new goals and functions appear, new goals and functions can be understood and (re)directed appropriately

It is apparent that this requires the application of a social theory that includes organisational learning and decision making. Any revised theory of technology deployment must emphasise the human element of the new human-machine system and cater for humans as they attempt to make sense of the new world into which they are thrust: an inter-subjective, shifting space in which they are intricately bound with a new information technology artefact, and which often makes little sense to them (Stapleton & Murphy (2002)). Systems (re-)design and deployment principles must be enhanced, or augmented, so that they can be folded into the overall management of the hybrid system. Furthermore, these approaches must be accompanies by sensemaking support which in turn feeds into and out of human centred systems engineering re-design process. A learning/explication support process is also needed which feeds into and out of technical and non-technical elements of the hybrid system, whilst treating it as a coherent whole (Stapleton (2003)).

But how does such a theoretical approach manifest itself in a practical systems engineering problem? The next section will set out a research study currently underway at the Waterford Institute of Technology and the Bulgarian Academy of Sciences. It shows how, by adopting a networking rationality, an entirely new application area emerges for assistive technologies.

3. ASSISTIVE TECHNOLOGIES FOR LEARNING DISABILITY

The American Technology-Related Assistance for Individuals with Disabilities Act of 1998, defines Assistive Technology as "any item, piece of equipment or product system…used to increase, maintain, or improve functional capabilities of individuals with disabilities" (P.L. 100-407 (1988)). The use of these application tools by people with learning disabilities generally falls under two methodologies; namely the *Compensatory* approach and the *Remedial* approach.

The compensatory approach applies when an assistive tool is used to circumvent the individual's deficit, thereby allowing them to avoid the implications of their disability. This is generally achieved by playing on their areas of established strengths rather than on their areas of weakness; for example, if an individual has poor or limited reading ability, then the use of taped texts or screen reading software allows them to avoid the necessity to read, rather than assisting them in the development of their own reading abilities. The remedial approach on the other hand does the exact opposite: AT is used to improve areas of deficiency, rather than simply compensate for them (Garner & Campbell (1987), Day & Edwards (1996), Raskind (1998)).

While both approaches can overlap, the compensatory approach is the preferred method when dealing with adults, and can be particularly appealing to those who have experienced 'burnout' from years of remedial solutions, that yielded little benefit (Raskind (1994), (Gray (1981), Vogel (1987), Mangrum & Strichart (1988)).

Individuals with learning disabilities are each unique in their profile, in terms of weaknesses, interests, strengths and experiences, therefore a tool that is of great benefit to one individual may be a hindrance to another. Similarly, what is suitable in one context or environment may be inappropriate in another (Raskind (1994)). In adopting an AT further consideration should include the level of learning disability involved, the individual's established strengths, abilities and skills, the environment in which the tool will be used, the context of interaction and the individual's "Technology Quotient", i.e. their ability and comfort with using technology (Bisango & Haven (2002), Raskind & Scott (1993)).

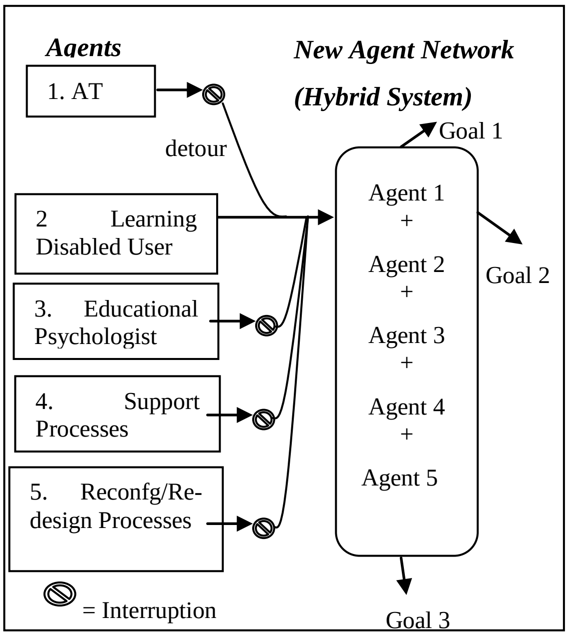

Figure 3. Interference & Goal/Function Transition diagram for the Learning Disabled Assistive System

For this paper the notion of the 'technology quotient' is very important. It specifically illustrates how the social context and social impact of the AT must be incorporated into the design process. We will see how this notion must be extended to ensure that the entire environment (social/technical context) must be co-designed according to human-centred (HC) principles which are proven to lead to increased self-esteem and other important individual and group benefits, in turn yielding far more effective technology-driven projects (Brown (1988), Reiff et.al (1992), Barton & Fuhrmann (1994)).

In the HC view, Assistive Technology usage must also be accompanied by the appropriate, on-going learning and psychological support processes. This will deliver sensemaking support into the socio-technical context (Stapleton (2003), Mills (2003)).

The considerations taken into account when choosing the method, by which training and support will be provided for the user, should be as stringent as those taken when choosing the tool. Individual deficits, previous experiences, preferred learning styles and personality traits should all be evaluated, addressed and catered for in terms of the approach taken in delivering the training material. This ensures that the technologically mediated environment makes sense as quickly as possible to the user.

It is important to note that, to a dyslexic individual, their learning disability can act as a brick wall or a locked door, between them and their understanding or communication capabilities. The way to unlocking that door is to find the correct key, but the key for each individual is as unique as they are themselves. By providing them with their own distinctive 'Assistive System', enabling them to become system literate and removing the fears and negative implications of system usage, only then can they find the right key to their own locked door.

Current AT adopts a 'one-solution-fits-all' paradigm. The technology generally is developed with technological constraints in mind, with little appreciation for key aspects of learning disability. There are ethical concerns here. The technology itself does not recognize the individual's need to adapt to the AT. Indeed, the keyword in Assistive Technology is 'Technology' rather than 'Assist'. Assistance in this case means far more than simply providing the user with a series of complex tools or functionalities. Instead, there are key psychological factors, which will enable (or otherwise) the user to effectively utilize the tools. Indeed, for some dyslexics, the experience of marginalisation could potentially be heightened by the provision of a so-called assistive technology which they can neither utilize effectively nor understand, simply because the technology is not designed for THEM as individuals. In fact, the technology development process never incorporated their worldviews into the design process. This exposes certain darker aspects of power within the systems engineering discipline as we find the 'learning enabled' designing solutions for the 'learning disabled'. In engineering such a solution the difficulty then is two-fold (at least):

To provide a system which treats human and machine as a single system, centred upon the individual human's needs

If we adopt Latour's ANT view we require an Assistive System as shown in figure 3. It is most likely that this diagram could include bi-direction (or even cyclic) lines between the hybrid system and the goals. So, for simplicities sake, the model incorporates a specific interference transitions that the arrows are unidirectional. It is understood that in the theory the entire process is necessarily cyclic and is unlikely to be discrete.

The diagram replaces a traditional context diagram but tells us a lot more than the primary interfaces and scope of the system, as would be set out in a context diagram. Figure 3 indicates the primary agents whose interests must be managed in order to develop a successful system. The diagram also centres upon the disabled user rather than the technology i.e. the trajectory of the user remains unaffected, but the trajectories of all other agents are the ones with which the project interferes. We can also identify from the relatively simply diagram the primary components of a sensemaking support process (agents 1, 3 & 4) as well as the need to include re-configuration processes in the design of the overall system. Using this simple diagram, we can immediately recognize that the technological agent must comprise a highly flexible and adaptive technology in order to support the ongoing re-design/re-configuration process. Furthermore, an interest which emerges is the need in the support process to link to other similar users. This indicates the need for an e-community (human network). We begin to see that we need a new form of assistive technology if we are to manage the interests of the other agents (especially agents 2 and 3). The AT must provide both flexible, intelligent, reconfiguration capabilities AND the ability to operate in a distributed environment. Such a technology is the Soft Computing Agent (SCA).

4. SCAS AND ASSISTIVE SYSTEMS

The logistics and costs involved in creating a system that is as individual and adaptable as the user, make such a system potentially non-viable. Through the use of the SCA paradigm however, an intelligent distributive system is not only achievable but also affordable. By utilising the intelligent, adaptable and distributive capabilities of SCAs the development of a distributed hybrid system, encompassing all five actors becomes a reality. (This should be all five agents but that may cause confusion between network agents and computing agents)

The SCA paradigm is a combination of Intelligent Agents and Soft Computing driven expert systems, (Lakov & Kirov (2000)) which enables the provision of appropriate training and support materials and processes to be made available to the user according to their profile of abilities and learning styles, as opposed to their geographic location and local resources. Through the use of an Intelligent Fuzzy Agent, virtual groups of 'similar ability' users can be formed, with the membership of each group being determined according a specified Fuzzy Rule Base. Such virtual groups enable the user to not only interact with other users but also to avail of technical and psychological support provided specifically according to their individual needs, while enabling the intelligent distribution and provision of training to be delivered in such a manner so as to allow the user to obtain the maximum learning outcomes.

4.1. 'Success'-ful AT

In this context it is readily apparent that 'success' is an elusive term. The diagram chows how the new hybrid system will generate a new set of goals and functions which will be difficult to predict. The outcome of AT will hopefully be a successful system, but success can only be measured in terms of the effective support that the technology provides in the overall context of a supportive learning environment. We see that, in fact, the technology as a stand-alone system, cannot, of itself, be successful. Indeed, the nature of learning disability is such that, from individual to individual, success factors will vary, and even change as people become better able to address their own learning difficulties. Any AT to date which has been 'successful' therefore may be regarded as a 'lucky break', because the support needs for people with these conditions vary from person to person.

Theoretically, this poses a significant problems for systems engineers seeking to develop purely technical solutions according to the traditional methodologies (such as SSADM). What is required is an approach which recognizes the dynamic nature of success, from person-to-person and from day-to-day.

4.2. Assistive Systems: towards Human-Machine HYBRID Systems

The diagram indicates that further attention must also be given to any psychological support that may be required. As with any technology, the psychological impacts can often be considerable, and be even further compounded by the psychological effects of the disability.

On-going support must be provided, to ensure the user is gaining only the intended benefits without experiencing any of the potentially negative impacts. This is indicated in figure 3 by agent 4, which will focus upon processes for the effectiveness of the new agent network (an aspect of explication support during the sensemaking process (Stapleton (1999)). Only when the user is provided with the correct tool, the proper training in their usage of the tool and when the necessary psychological and physiological supports are put in place, will the user be able to gain the full compensatory and/or remediatory benefits of the new system. By ensuring that the user has the knowledge, ability and support to use the tool and as a result, develop their own 'hybrid system', the deficits and strengths of each user can be addressed.

However the logistics of this requires serious consideration. How can geographically dispersed users be provided with on-going psychological support and appropriate training, in a timely and economical manner? The interests of agents in this area must be addressed in the assistive system.

5. SUMMARY: CONSTRUCTING A HUMAN CENTRED ASSISTIVE ARCHITECTURE

In summary, a research project is needed which must bring together entirely new approaches to the problem of assistive technology for the learning disabled. In this approach it must place the power over the final system configuration in the hands of the individual. It must also treat the human/technology system as a single system, not isolating (in the design architecture) the human from the technology. The research team recognised that such a solution must, therefore, incorporate key elements in the design architecture:

1. Distributed Technology components
2. Psychological Processes
3. Humans (users, medical professionals etc.)

The solution must enable each of these elements to leverage each other, coexisting in a single, synergistic system.

5.1 Summarising the application environment

A project has been developed that strives to use the capabilities provided by the Soft Computing Agents, to identify the best means of developing the technology and the associated support processes, so that the overall hybrid system is as effective as possible, thereby allowing the user to gain the maximum benefits. The aim is to provide, not just Assistive Technology, but more specifically an 'Assistive Systems', i.e. tools, training and support; that are tailored to the specific requirements and experiences of the individual user. A further aim is to distribute these systems based on the user requirements, as opposed to the user's geographic location, in an efficient manner in terms of time and economics.

A project team has been established to develop solutions in this area. The international team comprises leading experts in intelligent systems, information systems methodologies and e-medicine. The local test site incorporate a team of researchers from the Information Systems, Organisations and Learning Research centre working with the Disability Support Unit. The project is to be targeted at students in higher education who experience learning difficulties. The project will ensue according to the following steps: -

1. Each student will be assessed in terms of their areas of weaknesses, strengths, personality, preferred learning styles and previous experiences. This information will then be used to build an individual profile of the students, according to a determined set of criteria.
2. This profile will then be fed into a central database, which will house the information relating to all students involved in the study. It is proposed that all participants will be under graduate students in their second/third year of study, and will be registered with the appropriate authorities within their academic institutes as being dyslexic.
3. A set of three groups will be defined using a Fuzzy Rule Base. These groups will be homogenous groups of students that have the same or similar levels of ability and disability. The membership class of each group will be determined using Fuzzy Logic, i.e. how strongly a students profile relates to the membership criteria of a particular group.
4. Systems of Intelligent Agents will be used to search through a central database and to assign each student to a group according to their level of membership class.
5. Data, such as training instructions and communication arenas will be dispatched throughout the system, with each student automatically being provided with only the information that is relevant to them according to their group membership.
6. SCA systems allows the formation, automated maintenance and interaction of groups according to specified criteria, as opposed to geographic location. This means that specialised training and support for the student is possible and can be designed, solely according to their individual needs and learning styles. This enables the provision of an 'Assistive System' consisting of the tool, support and training, as opposed to the traditional approach of an 'Assistive Technology' comprising of only tools & limited instruction.

6. CONCLUSION

Systems engineering methodologies research has not tackled directly the power relations associated with advanced systems. It is readily apparent that adapted agent network theory can be effective in helping us to understand key aspects of the complex relationships between humans and technology. By adopting the approach set out in this paper, the systems engineer can also identify human-centred aspects associated with the social impact of a new technology in a reasonably coherent way.

This paper sets out a project, currently underway at two European sites. The project shows how a revised, interdisciplinary and agent-network view of a well established problem (the provision of AT for learning disability) provides a fresh approach. It shows how the perspective applied here can illuminate potential points of failure, inappropriate underlying assumptions associated with the ways in which the human agents will respond to the new technology. More importantly, the approach denotes a paradigmatic shift which re-places humans into the centre of the technology research programme, with the associated ethical implications of that focus.

This paper focuses the attention of engineering research activities on the agents in both the centre of the process (laboratory equipment, the engineered technology) as well as the fringes of the society in which the research is conducted (for assistive technologies, the people with special needs participating as agents with a key stake in the project). Whilst this is a deliberate 'mis-reading' of Latour's instrumental realism, it is useful since it shows how a combination of Foucault's knowledge-power views and Latour's realism can provide a powerful basis for revising technological research. Whilst this paper specifically shows how such an approach can be utilised in a health informatics project, it has wider implications for a variety of automation engineering research positions.

ACKNOWLEDGEMENTS

The authors thank **Enterprise Ireland** for their support in funding this research.

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