Learning difference and digital technologies: a literature review of research involving children and young people using assistive technologies 2007-2010

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Introduction

This literature review is designed to build on a previous publication (Abbott 2007a) and to indicate changes in the scope and trends found in assistive technologies and related research. The period covered is from January 2007 to December 2010, using date of publication as the marker. A wide range of academic journals and conference proceedings were searched by keyword, although not all searches led to relevant research:

JOURNALS
Journal of Assistive Technologies
International Journal of Inclusive Education
British Journal of Special Education
Support for Learning
Journal of Research on Special Educational Needs
International Journal of Special Education
Journal of Education Policy
British Educational Research Journal
Computers and Education
Journal of Educational Computing Research
Interacting with Computers
Human Computer Studies
Universal Access and the Information Society
IEEE transactions
ACM transactions
Lecture Notes in Computer Science (AAATE etc)
Cyberpsychology and Behaviour
Presence
International Journal of Virtual Reality
Disability and Society
Journal of Applied Research in Intellectual Disabilities
Journal of Intellectual Disability Research
Learning Disability Practice
Technology and Disability
Research in Developmental Disabilities

CONFERENCE PROCEEDINGS
International Conference on Disability, Virtual Reality and Associated Technology

A number of decisions were taken with regard to the presentation of findings. As discussed elsewhere (Abbott 2007b), previous attempts at classifying this literature have tended to do so by form (hardware, software) rather than focusing on use, as is our intention here. We therefore present the literature within three broad categories:

  Technology uses to train or practise
  Technology uses to assist learning
  Technology uses to enable learning

In many ways, these can be seen as chronological stages within the development of much educational software and assistive technology, with early emphasis on the automaticity and patient repetition enabled by computers leading to an explosion of drill and practice software. Over time, developers produced tools that assisted learners in more inventive ways; and, more recently, truly innovative technologies have sometimes enabled learners to access education where this was impossible before. However, this chronological lens is a flawed one, since innovative enabling technology also appeared very early in the development of the sector, and drill and practice remains present and very much active.

Shortly after the Futurelab review appeared in 2007, Salminen (2008) published a similar review focusing on European research related to assistive technology. Covering the period 2000 to 2005, Salminen looked only at research related to children, in only a small range of journals and with an emphasis on the assistive technology itself, according to the ISO 9999 classification. ISO 9999 (www.iso.org) is quite specific in its definition; it includes any assistive technology used by a person with a disability, but which requires the assistance of another person. The full standard is a lengthy and complex document which can be purchased from the ISO website. The ISO definition is quite restricting if strictly applied, and ISO 9999 also does not cover devices used by healthcare professionals. It is perhaps therefore not surprising that the author found little evidence of assistive technology research, at least by her definition.
Overall the amount of European research is very limited... The number and focus of the studies seems to relate to research funding that has been available in Europe and indicates the need for future funding.

(Salminen 2008: 176)

Salminen also makes the point that longitudinal research is needed in the sector, and that its complexity may also be part of the reason for the apparent dearth of literature.

AT is a complex phenomenon that takes place in real life, involving technology, humans and activity, while taking place in different contexts... Given the complexity of the whole phenomenon, it is a significant challenge to decide on the correct [methodology]... It may even be that methodological compromises in the studies related to children and AT do not fulfil the criteria of those who fund research or review journal articles, and thus the whole research area becomes more marginalised than it deserves.

(Salminen 2008: 177)

Issues of classification, nomenclature and definition have been addressed by others attempting to provide an overview of assistive technologies, often when editing special issues of journals. Editors such as Raymaekers (2009) have sought to bring clarity and understanding to new areas: in this case, enactive interfaces. Gesture input and haptic devices are among the technologies in this special issue of Interacting with Computers, and these are technologies to which we will return.

Users of assistive technologies, especially young users and those who support them, have not often been asked for their opinions or been involved in research. This has begun to change, however, particularly within projects such as Devices for Dignity (www.devicesfordignity.org.uk). At an early stage of that project, researchers asked assistive technology users what they wanted from the technologies they use, and the questionnaire they developed for this is now available to others (Townend & Judge 2009). Using a combination of interviews with users and questionnaires for carers, the researchers sought to address an issue which has faced many in this field.

There are no tools which currently facilitate the user to consider in detail all the features of an AAC device... It is proposed that the topic-guide, prompt sheets and questionnaire form the basis for a decision-making tool to aid AAC device selection by users and/or professionals. The findings related to users' perceptions of communication and design will be published at a later date.

(Townend & Judge 2009: 38, 39)

A recent exercise as part of a keynote address at an Australian conference (Abbott 2010) involved the rapid gathering of "perceptions, experiences and desired changes" from a large number of delegates. Unsurprisingly – perhaps – the more than 600 responses clearly indicated that what these carers, teachers and therapists look for from assistive technologies are low cost, a high degree of reliability and the best possible accessibility. Interestingly, they were less eager to see new and ever more innovative developments, preferring instead to see further development on the three issues above. Not perhaps a message that some commercial developers would wish to hear, but relevant nonetheless, and one that is coming nearer with the move of assistive technologies to mainstream and sometimes more robust devices.

New approaches are called for in some of the literature however, with the rise of Universal Design for Learning – sometimes known as Universal Learning Design or Design for All – prominent in many journals. Rose and Strangman (2007) call for Universal Learning to be adopted in order to challenge what they see as the limitations of other approaches that deny the range of individual differences. Basing their argument on cognitive science research, they suggest that cognition and learning are based on the interaction of three neural networks: recognition, strategic and affective. Rose and Strangman describe these networks and then explain how the Universal Design for Learning framework is built on this understanding and recognises the concept of individual learner differences.

Approaches to design, which stress a Design for All approach, argue that the aim should be to "provide for diversity through design rather than accommodation" (Horton, 2006, p xvi). Forrester Research (2004) has shown that the majority of people who use computer systems have some form of disability (57%). They found that a significant number of users of accessibility features (32%) and users of AT products (35%), such as trackballs and screen magnifiers, had no difficulties or impairments. People prefer accessibility options and products because they find them easier to use, more comfortable, or they want to avoid developing a health problem (such as Repetitive Strain Injury). This research was carried out for the Microsoft Corporation, which proposes designing accessibility into systems (Microsoft, 2009). According to PopCap games, one in five casual
gamers has some form of physical, mental or developmental disability (PopCap, 2008). This research strongly supports the designing for diversity approach, since a significant number of people like accessibility features and AT products, and because a lot of customers have disabilities of varying degrees.

User Centred Design approaches (e.g., Brown et al, 2011a) incorporate users and stakeholders needs into the design process, and include iterative evaluation to ensure that the system meets the design requirements and the user’s needs. User Centred Design (UCD) focuses on the need to take user requirements into account in order to create usable systems that will be used. The USER fit methodology is a user-centred design approach specifically for AT development, which again aims to take user requirements into account, to assist AT developers in addressing the issue of usability in design. It is again an iterative and evaluative design process. Evaluation is very important, and this again is becoming increasingly important in learning systems, ensuring that systems are usable and address the learning requirements, rather than being used for their own sakes. The RECALL and AEGIS projects both address the needs of stakeholders, and of evaluation, as part of the UCD approach.

There are other issues, too, that do not fit neatly – or even to some extent – into the three broad categories we come to below. The role of the carer, for example, can be vital for the success or otherwise of particular technology–assisted learning practices. User–Centred Design (UCD) approaches, which analyse the characteristics of users, their activities and context of use, also encourage consideration of all users, including carers and trainers. The significant role for carers is made clear in a paper describing two case studies where users gained little of the expected benefit from an interaction with technology, due to the inappropriate or unhelpful interventions from support staff (Williams 2008). Interactions with support staff also play a role in a pilot PhD study designed to test methodology (Bailey 2009; Bailey & Bunning 2010). In this case, support staff formed an integral part of the project and they were vital to its success.

Too often, however, time is not available to consider the full implications of the carer-user relationship and its affordances. The emphasis, especially in policy documents arising from research projects, is often on assessing rapidly and then allocating equipment, with less attention given to evaluating how effective it has been, the case for more attention to the latter being well made by de Jonge (2007). Wider issues around the interface between assistive technologies and disability rights are important too (Konur 2010), although these are not addressed as often as they might be.

Within formal schooling, key issues need to be resolved around the way in which Virtual Learning Environments (VLEs) enable – or obstruct – a wide range of different learners to participate. The World Wide Web Corporation’s Web Content Accessibility Guidelines (currently version 2.0; W3C, 2008a; 2008b; 2008c) set global standards for Web accessibility, and there are many tools available to evaluate compliance. Whilst there are legal requirements for such VLEs to be accessible, there are also good practice guidelines such as W3C and Horton (www.universalusability.com/access_by_design/index.html), as well as general advice from agencies such as Techdis (www.jisctechdis.ac.uk) and others (Evett & Brown, 2005; Brown et al 2010). In addition, tools such as Fix the Web (2011) enable users to report non-accessible content, following which teams of volunteers will contact the providers with advice on how to improve their provision.

With a call for VLEs to reflect real-life experiences, as in the Editorial of a special issue of Interacting with Computers (Coughlan et al 2007), we must ensure that it is the whole of “real life” that is reflected and not just a homogeneous group of standard learners, if such a group can be said to exist. As McKay (2007) points out, Web-mediated courseware design can offer new opportunities for highly graphical and visual material, which can be not only helpful to particular users but can enhance the learning experience for all. This view is supported by Sanchez et al (2008) who call for a greater range of modalities in computer-based learning. To encourage such developments we can to some extent look to the standards agenda and the development of tests of accessibility and the legal requirement to address the issues that arise (May & Zhu 2010). Testing alone, however, is not enough: we need to show that good accessible courseware design is in the interests of all.

Technology uses to train or practise

It has been suggested (Abbott 2007a) that technology fitting into this category has too often been seen as central to the needs of those with learning differences, despite the close association with simplistic behaviourist models of learning. This use of technology is persistent however, and continues to be practised and researched. Too often, unfortunately, the focus of this research is an evaluation of a particular product, often by someone closely associated with that product or its originators. Such research, although not without
interest, is likely to be unconvincing within wider research circles. On some occasions, it is clear that much more of interest could be said in a more wide-ranging paper, as is the case with Jones (2008) on a particular software title for learners with dyslexia. Within his anecdotal description of his use of the program with a range of learners, Jones raises some important issues and it would be helpful to see these developed in a more academic paper.

Some technologies have been developed to train for specific skills or practices. A PhD student has described (Umanski et al 2010) the development and evaluation of a tool for conducting speech rhythm exercises. The game prototype, designed for use by speech and language therapists, presents sequences of syllables in specific rhythmic patterns, with this interim paper describing limitations to date and further developments proposed. In Taiwan, many researchers have focussed on the affordances of technology for users with a range of impairments, and a group of researchers have developed a music-learning system aimed at those who have a hearing impairment (Yang et al 2007). The aims of the system were to train in the differentiation of tone, and to enable the learning of what is described as song. In its present state, however, the system appears to offer essentially practice opportunities for identifying single notes. Liu and Hong (2007) attempted a more holistic type of support for hearing-impaired students through the development of extra-curricular support via smartphone, which was found to be manageable and effective. The focus for Lin et al (2008) was software to teach word recognition to those identified as having learning difficulties, although it would seem likely that the program outlined would provide practice rather than learning opportunities, since the activity mainly consisted of the recognition of the appropriate Chinese ideograph alongside a graphic symbol, which is then faded out gradually.

Navigation strategies were the focus for a group of researchers (Groenewegen et al 2008) who developed virtual worlds which could be used to train learners for independent living. There have been a number of such studies looking at the use of virtual reality to train for real life navigation (Abbott 2007a), but there are sometimes limitations in the amount of data on transferability of skills such as navigation from the virtual to the real world.

The rapid development of access to the Internet for all users has led to a similarly rapid development of Web-based training sites and other mechanisms for providing online practice. Researchers from five European countries working on the SEVERI project (Staracic & Niskala 2010) created an e-learning environment for students with a range of special educational needs, and then tested and evaluated its effectiveness in special vocational schools in Finland, Lithuania and Hungary. The team found evidence of greater student autonomy as a result, and an increased ability to manage communication difficulties.

Animated sequences have been popular as the medium for training since the 1950s, with 16mm films now replaced by digital sequences. Researchers in Germany (Spannage et al 2008) compared the effectiveness of animated sequences and other devices such as training wheels (programs with reduced functionality) or text manuals. The task involved was to learn how to use a spreadsheet to solve Maths or Physics problems. Working with more than 150 thirteen year olds, the research team found the results for training wheels were inconclusive, but that the use of animated training sequences was clearly more effective than the use of text manuals alone, and that this effect was more marked when working with charts than in the area of formulae. Mathematics was also the curriculum area that was the focus for the work by Brown and Standen (2011) and by Seo, Pedrotty and Bryant (2009) on what they describe as computer-assisted instruction (CAI) for students with learning disabilities. In the latter case, however, the team found that CAI was not effective for this group, although it might have been for smaller groups. They did, however, recognise that there were aspects of their methodology that limited the possibilities for validation of results. Building on this work, Seo and Woo (2010) again focus on Mathematics and students with learning disabilities in their study of the use of a particular CAI program. As with all such single-product evaluation papers, there are limitations to what can be claimed, especially where the research team are also the originators of the product. However, the project team do identify three areas they describe as “critical user interface design features” and these are “instruction-driven, manifest structure and adaptive interaction interfaces” (Seo & Woo 2010: 374). They then develop seven implementation guidelines, interestingly including the use of animation as in Spannage et al (2008).

Therapists, as well as teachers, have long used technologies within educational environments, or to support what goes on there. Saz et al (2009) describe a study involving Speech and Language Therapists (SLTs) working with a range of young people with a degree of language impairment. Recognising an increasing demand for SLT support, the team developed a semi-automated system to provide interactive speech therapy. The particular aspects of therapy involved included aspects of speech production, articulation and language understanding, and with a particular focus on the needs of those children with neuromuscular disorders. As the team
recognised, human-computer interaction in this area requires highly developed and sophisticated speech analysis, speech recognition and speech verification algorithms, particularly in respect of the speech variability encountered in this participant group. They found that such semi-automated systems could indeed provide effective support and that “speech technologies jointly with AAC systems and a simplified user interface allow the unsupervised automation of the process of speech and language therapy” (Saz et al 2009: 965). Although the topic is not discussed in the paper, it is perhaps relevant that this research took place among speakers of Spanish, one of the most phonically regular languages.

A more recent development linked to this type of technology implementation, though often transcending its limitations, is the use of what have come to be known as serious games, for example being used to teach employment skills to young people with intellectual disability (Sik Lányi et al, 2010). Serious Games are becoming more prevalent, and are particularly relevant to the field of disability and learning. This is because they allow enjoyable repetition with gradual increase in challenge, allow users to work at their own pace and make as many mistakes as they like without irritating or being judged, and encourage active involvement and experience of control. They provide access to educational opportunities and experiences. It is important however, both for these and for other uses of technology, to evaluate their effectiveness.

Such games have been described (Puttnam, 2009) as ethical laboratories that show you how things are and how they could be, and can therefore be used to influence change. Multiple player online games and other social networking tools offer not just a way of having an online presence; they also serve as incubators of a new pop cosmopolitanism and an ability to navigate in an increasingly globalised, diverse and socio-technical world (Steinkuler, 2008).

Savidis et al (2007) describe how they have used serious games with people with learning disabilities in Crete, finding these to be pleasant, motivating and highly engaging interactive experiences, improving training and learning. Motivation and engagement were also issues that arose during an intervention by a team of psychologists in the Netherlands who aimed to explore the potential of technology to significantly improve short term memory (van der Molen et al 2010). The researchers developed a version of an Odd One Out game in three modes: adaptive, non-adaptive and the control, with no demand on memory. They found that visual short term memory improved significantly post-test and after a further ten weeks in the adaptive group, compared to the control group, and the paper makes the claim that this is “the first demonstration that working memory can be effectively trained in adolescents with mild to borderline intellectual disabilities” (van der Molen et al 2010: 433). An earlier study (Brown et al 2008) showed the effectiveness of games to improve the memory skills of people with intellectual disability.

In order to access any of these technologies, appropriate interfaces need to be available. These continue to be researched and developed, with Visell (2009) providing a review of, for example, varieties of touch interface and the principles of tactile sensory substitution, and Evett et al (2009) considering the use of Wii technology. Touch was the focus of research in Sweden (Moll et al 2010) on the extent to which an audio and haptic interface encouraged collaboration between sighted and blind users. Unfortunately, the research design adopted used pairs of blindfolded and sighted users, rather than involving blind people as participants. The results, however, were encouraging and suggested that the use of sound within a haptic environment would be of assistance for blind users.

Another interface used by a team in the United States was a PDA (personal digital assistant) as a cueing device. As part of a programme to teach fire safety, the researchers (Burke et al 2010) worked with a six young adults on the Autism Spectrum and found that it was only after the introduction of the cueing system that five of the participants could respond to the behavioural skills training. The team suggest this raises the possibility of such interfaces assisting the prospects of learners with ASD being employed in future.

**Technology uses to assist learning**

Although there is some discussion in the literature of basic design principles for inclusion (Langdon & Thimbleby 2010), much of the research into technology uses to assist learning is focussed on a particular technology or way of working. There has also been a particular emphasis on the needs of those with sensory impairment, although more recently there has been more attention to the needs of users with cognitive difficulties, as in Gregor and Dickinson (2007), who propose an interaction design perspective when creating resources for this group of users. Davies and Dautenhahn (2010) have published guidelines for the design of software – and software trials – for children with autism. The guidelines were developed from their own work on a particular project, but were then generalised in order that they could be used by others for similar work
elsewhere. McMorran (2009) provides a detailed case study of a young head switch user who eventually progressed to the use of eye gaze. Covering this learner’s development from the age of 3 to 8, this longitudinal study is an example of the type of detailed research which is needed in this area. The EU-funded COGAIN project also examined eye-gaze technology, and the report (Majaranta & Bates 2009) of a conference set up by the project provides a useful summary of the work completed and an introduction to the more specific papers included in this special issue of Universal Access to the Information Society.

Although many assistive technologies have been in use for many years, little is known in some cases about how they are used. This was the focus for McGuiness and Farrand (2010) who investigated how people use their voice output communication aids (VOCAs). They found that VOCAs enabled greater communicative range and autonomy for some users, but not all. In some cases, additional impairments such as learning difficulties affected the impact of the assistive technology in use. An international team investigated a similar area (Lancioni et al 2007) in their study of three adolescent VOCA users with more severe learning difficulties. They found potential for the use of VOCAs by this group who accessed them through handswitch or headturn microswitches.

A team from the Child Computer Interaction Group at the University of Central Lancashire looked at the use of pen, keyboard and graphics tablet for the entry of text (Read 2007). They found that lengthier texts were produced by the children (who were aged 7 and 8 years) using a graphics tablet than the other alternatives; there are implications here for the touch-based input interfaces used on mobile phones. Occupational therapy research has much to offer in this area, particularly with the clear identification of the type and nature of difficulty with handwriting (Hen, Josman & Rosenblum 2008), and the potential of computer-based rehabilitation.

Speech recognition is now a well-established technology which is much more affordable than was previously the case. Automatic Speech Recognition (ASR) is usually taken to mean the use of speech technology to dictate a document which will look the same as that produced through a keyboard, with punctuation and formatting in place. A team at the University of Southampton looked at the potential of ASR for users of assistive technology (Wald & Bain 2008), and found that, at least within the learning context examined, there was clear potential for ASR use to assist with note-taking, online searching of multimedia, automatic captioning and communication skills. A major difficulty for researchers in the speech recognition field is the lack of tested and reliable instruments, although current work on user response as reported by parents (Griffiths et al 2009) should result in enhanced capability in this area.

Similarly, though with a focus on established software tools, researchers from two US universities examined the use for emergent literacy of Writing with Symbols (Parette et al 2008) and then Clicker 5 (Parette et al 2009). The main focus in both papers was on the evaluation of the software, and within a definition of literacy difficulties with a strong link to phonological deficit models; the second paper also interestingly contains a defence of new technology use, although in the absence of a supportive literature review. Recent and current PhD studies also focus on graphic symbol use though within more developed theoretical frameworks and across the disciplines of teaching and speech and language therapy (Greenstock & Pampoulou 2009) or the role of symbols for accessing literacy in the mainstream school (Pampoulou & Detheridge 2007, Greenstock 2009). Specific symbol sets such as Makaton, Widgit or PCS; or symbol-enhanced teaching systems such as PECS or TEACCH; have also been the subject of research, a recent example being the study of current attitudes to Makaton within inclusive education paradigms (Sheehy & Duffy 2009), which showed how that symbol set has moved from being a remedial technique to being seen as a tool for inclusion. The rapid development of symbol use within mainstream schools is also at least part of the driving force behind the development of inclusive symbol resources by multi-disciplinary teams. Although this work has often taken place in speech and language or occupational therapy settings, it has also happened at school and college level. An example of this would be the series of innovative interdisciplinary projects in which a mainstream school worked collaboratively with FE students with learning difficulties and occupational therapists to create symbol and digital video resources (Mead, Mead & Williams 2009; Mead, Mead & Williams 2010; Mead, Mead, Sebuliba & Williams 2010).

Braille could be seen as one of the first assistive technologies, and computers have enabled it to be a much more varied and useful tool. Audio, too, has much to offer those young learners who are blind, and researchers at the University of Iceland have produced a review of the efficacy of audio vs. Braille for a range of everyday tasks (Shimomura, Hvannberg & Hafsteinsson 2010). The study aimed to look at how young learners use technologies such as screen readers with audio or Braille, and to identify the barriers that may be found, as well as the strategies that support their use. The researchers also offer recommendations for
interface designers and suggest future areas of research. Screen-readers have been much used by blind learners, but the various menu hierarchies that may be created on websites are interpreted variably by different reader software. A variety of hierarchical menu structures has been found to lead to varying results (Hochheiser & Lazar 2010), with this study of blind screenreader users showing better results with broad, shallow structures than with narrow, deep ones, a finding they note as having been replicated in previous work with sighted learners.

Skimming and scanning remains problematic for blind Web-users, and browsing shortcuts are mechanisms that may help in this area (Kouroupetroglou, Salamantis & Manisaris 2007). Using a specialised Web browser offering enhanced screen reading, the team present the technology as a vital counterbalance to low accessibility. It would seem important that this work continues, since it has been shown (Zúñica & Clemente 2007) through research with visually impaired users that they see the Internet as a valuable tool for accessing information and communicating with others. However, the researchers also report that the same users found frequent and important problems of accessibility that reduced the effectiveness of these resources. Other research (Manset-Williamson, Dunn, Hinshaw & Nelson 2008) went further and examined the role of a self-questioning strategy as a way of enhancing metacognitive strategies on the part of the learner who is struggling to use screen-readers meaningfully. The strategies were found to be helpful with some users with learning difficulties, but not all.

Similarly, signing is a very well-developed language in use among many hearing-impaired and deaf learners. Work continues on the effective translation of speech to avatar-based signing, and Elliott et al (2008) provide an overview of developments in this area, focusing on sign language generation from English text and the difficulties presented by grammatical and other issues.

As with the technologies for practice, there is considerable work on technologies to assist learning within Mathematics and Science curriculum areas. Young learners in the Netherlands who were identified as having learning difficulties were tested with an ICT-based assessment which was also described as a dynamic visual tool (Peltenburg et al 2009). The aspect of Mathematics involved was subtraction, and the team sought to use the tool to discover the strategies by the children and their potential as learners. One finding was that pupils could benefit from only partial support by the tool. Within the wider mainstream curriculum, and indeed within professional adult training environments, animation has long been seen as a modality offering clarity, engagement and control for the author. One mainstream school (Burdett et al 2010) has developed a wide range of animated help modules to support students with learning difficulties who have been included in a mainstream school. Future amalgamation of this work with other developments on automated captioning could be mutually beneficial. Much school work with animation is located within the literacy curriculum, and research located within the mainstream literacy setting increasingly takes account of the affordances and barriers associated with technology use (Andresen 2007). Digital video production in general has been shown to be an effective technology use for learners showing signs of challenging behaviour and those with learning difficulties (Orr 2007), although sufficient time must be allocated for the activity to be successful.

Mobile computing has developed rapidly in recent years and offers an increasing range of assistive technologies. A review of this field (Power and Jürgensen 2010) focussed in particular on mobile technologies to assist learners with visual disabilities. Covering PCs, PDAs, media players and mobile phones, the authors look at a wide variety of options now available to present textual, graphical, mathematical and Web-based documents through audio and haptic modalities. Stock et al (2008) evaluated software which aimed to increase independent access to mobile phones by people with learning difficulties, through the use of an off-the-shelf phone with special software installed. Mobile phone interfaces are also the focus for a paper looking at design principles that could improve accessibility for those who struggle with literacy (Lalji & Good 2008). Learning in the widest sense is the focus of a study of the use of a wrist-worn navigating device (Fickas, Sohlberg & Hung 2008), in which the authors compare four different prompt modes for people with cognitive impairments: an aerial map, a point of view map, audio but no image or text with no image. Participants performed best when given audio prompts, and the majority also preferred this mode. A similar result was presented (Zentel et al 2007) when investigating the barriers facing Web users with cognitive difficulties; audio feedback was found to be more effective than unstructured graphical symbol support. The way forward for these users may not be through extra facilities at the Web browser level, but through designated portals which can enable users to explore the Web independently and to a greater depth. The team developing one such portal (Williams & Hanson-Baldauf 2010) have indicated the key areas of difficulty, such as scrolling and the need to surf first to get an overview, but have also noted the very limited amount of empirical research in this area.
Games and puzzles have a long history of use within assistive technologies. Children on the autism spectrum have been given the opportunity to access a puzzle through innovative and interactive technologies such as multimedia tables, tangible technologies or virtual environments (Battochi et al 2008). The Collaborative Puzzle Game (CPG) described in this paper was used to study social interactions among boys with ASD and those with typical development, as well as testing the system as a rehabilitative tool. The CPG promotes collaboration since actions on digital objects can be performed only through the simultaneous touch of two or more users. Also working with children on the autism spectrum, Davis et al (2007) identified a deficit in narrative comprehension among these young people, and sought to address this through an interactive software system which would also recognise the social world in which they live. Reporting on this longitudinal study, the authors describe enhanced understanding of narrative components and a correlation with real-world narrative comprehension tasks. Shih, Shih and Wang (2010) also looked at technological prompts for collaboration, as they developed a driver that would allow two users with multiple disabilities to co-operate in moving a mouse. They found that the combination of two users led to more effective and accurate mouse pointing. Liu, Conn, Sarkar and Stone (2008) took a different approach by investigating the ways in which technology-based tasks might elicit the affective states of liking, anxiety and engagement that they report as being important in autism intervention. The system they describe involves constant monitoring by a therapist who uses an assistive therapeutic tool, a development the authors report as the first time that the affective states of children with ASD have been experimentally detected by way of physiology-based affect recognition technique.

Users in Finland with a variety of levels of visual impairment played a series of games using audio and other support (Evreinova, Evreinov & Raisamo 2008). In their paper, the authors discuss the need to recognise that blind people live in a soundscape which is egocentric rather than three-dimensional, and that interaction design must recognise this. Serious games have been developed within this area of practice as well as within the use of technologies to train or rehearse. Sánchez and Rodríguez (2010) developed a sound-based videogame in Chile, to be used alongside a haptic device for improving orientation and mobility in blind children. Results showed a high degree of acceptability on the part of the target user group, and researchers hope the next phase will show significant gains in the development of tempo-spatial orientation skills of blind children when navigating in unfamiliar spaces. Working with a different colleague (Sánchez & Sáenz 2010), Sánchez has also published research on navigation for the blind through an underground railway system, with the fieldwork having taken place in the Santiago Metro. The results showed that the virtual environment tool developed could be an adequate and complementary tool following further development work. A team from Nottingham (Brown et al 2011) have used serious games alongside location-based technologies for young people with severe learning disabilities and additional sensory impairments. Location-based services enable learning to take place in a real context, with all the support that this context and assistive technology can provide when working in tandem: for example, when route learning in a real context by young people with disabilities using an Android device. The Route Mate system used by this team allows the target audience to plan, rehearse and then independently travel new routes to work, and to other public and leisure services. It is crucially a route learning system and not a route guidance system, as the latter can suppress spatial map development.

It seems likely that robotics will have much to offer in the field of technology to assist learning, and indeed to assist daily living, although the latter is beyond the scope of this review. The availability of gesturing technologies led to exploratory work with motor disabled learners who were able to interact with a multimedia robotic device (Petersson & Brooks 2007). More recently, Standen et al (2011) have evaluated the use of the Wii Nunchuk as an alternative assistive device for people with physical and intellectual disabilities who normally use switches to interact with computer software. For most functions of the switch, there was no significant difference between the participants’ performance using the Nunchuk and their familiar device and some participants’ performance was better whilst using the Nunchuk. The researchers suggest this merits it being offered as a possible alternative to currently available switches for those with physical difficulties affecting their grip.

Assistive play was the focus for other robotics development in Canada and Portugal (Cook, Encarnação & Adams 2010). From a rehabilitation engineering and robot design perspective, the authors aimed to define a set of desirable characteristics for robots and assistive play. Their early work has shown that, after watching the assistive play, parents and teachers thought that children were more able than they had assumed. Raya et al (2010) worked with very young children to investigate whether a head control mouse would be an effective solution for learners with motor disabilities. They found that their target group could control the cursor in this way, although they had more difficulty with finer movements.
Assistive technologies also have learning-related uses to enable young people to participate enjoyably and meaningfully in a range of activities. This was the focus for the use of a motion-sensitive environment which provided interactive control of responsive multimedia (Brooks 2008). The author relates the workshops described to a series of research activities around this technology and its use, suggesting that there is fertile ground here for assessing the dynamic relationship between technologies and human response. Not all aspects of social networking are as accessible to assistive technologies users as might be the case, as Bates, Vickers and Istance (2010) show in their discussion of the use of gaze interaction with on-line communities. Within a longitudinal study of eye-gaze technology (Bates et al 2007), and focussing in particular on Second Life, the authors show that current access possibilities do not offer effective gaze control and thus impair the ability of users to make their disability transparent. Other technologies may seem much more accessible, and Skype, for example, has generated a great deal of interest in view of its minimal cost and great attractiveness to young people. Early research into its affordances for learning (Harrison & Robertson 2008) is encouraging. Similarly, Web-based libraries open up possibilities for collaboration and cultural exchange (Komlodi 2007) and enable the development of suitable online repositories. With such a range of assistive technologies available, it can be difficult for even an informed professional to be aware of the whole range of possibilities. Some see the toolkit approach as a way forward (Judge, Floyd & Jeffs 2008) although this may not be the answer in all cases. Others locate the driver for assistive technology use as being the legislative framework in position, as is the case with a review of implementation in one Canadian state (Morrison 2007) which showed that the most important factor was teacher attitude and comfort with technology, a finding which has been described in the wider ICT and education literature over many years. Too often, ICT may be all-pervasive but not used particularly to assist or enable inclusion, as Brodin and Lindstrand (2008) found in their study of young children with motor disabilities. There is a well-developed literature on the use of assistive technologies by people with AAC needs, for example a study of children in hospitals (Sherlock 2008) which refers to previous literature on the topic and notes again the preponderance of low-tech devices. Outside of AAC, autism and to some extent sensory impairment, there is still much less research literature on technology uses to assist learning than would be expected given the very large number of contexts in which this takes place. Evaluation of particular devices or software are helpful, for example a recent study of particular combinations of mouse and computer (Shimuzu et al 2010), but it is longitudinal and wide-ranging research into the uses of assistive technologies rather than the device itself which is of most assistance – and impact – for the end user and associated carers.

**Technology uses to enable learning**

Perhaps amongst the most truly enabling of technologies are those that make it possible for people with no ability to communicate to do so. This was the focus of a recent study (Nianou et al 2010) that investigated the use of communication aids with people with locked-in syndrome. The team focussed in particular on the affordances of communication aids, their impact on therapy and the particular challenges of locked-in syndrome. Voice Output Communication Aids – VOCAs – have long been an essential component of the technologies resource bank, but there is a need for these to continue to be developed and their features refined and improved. Particular users, such as students in Further Education, will have specific needs and a case study (Howarth & Slaughter 2009) identifies these and suggests some possible solutions. Much younger children use VOCAs too, either to develop communication or to make it possible at all. Assessing the needs of these younger children is particularly challenging, and four case studies (Harding 2009) identify the key issues to be considered, such as the receptive language capability of the child and whether the necessary cognitive pre-requisites are in place, and goes on to argue strongly for a more considered process of implementation.

Aesthetic and creative aspects of the use of technology feature less often in the literature, but can be enabling in a most profound way. Working within a rehabilitation framework, the use of an immersive, multimodal user-controlled installation in France was found to have great potential (Ghedini, Faste, Carrozzino & Bergamasco 2008). The installation, Passages, offered users the opportunity to create, explore and interact with a virtual environment in real time. Grierson (2008) also addressed creative uses of technologies, in his paper about children with multiple disabilities, including deafness and autism, making music with images. The paper describes the technical basis for the system, which involves real-time transformation of sound into moving images, and then back to sound again. Although the project detected some issues to be resolved, the results also include the potential for the use of the system for voice training, as became clear during trials at a school for the deaf.

It is also unarguable that many technologies used by blind people are truly enabling, in that without those technologies it would be very difficult if not impossible for those users to access the resource in question. Of
course, training remains paramount, and there is no shortage of literature to show the difficulties that arise when there is a lack of technical competence at home or school, even in a relatively affluent country like Norway (Vik 2008). An Italian team describe (Dini, Ferlino, Gettani, Martinoli & Ott 2007) how they evaluated the accessibility of educational software aimed at students with low levels of vision. They propose an educational software accessibility checklist which is intended to be used by teachers who may have little experience of children with limited vision, and covering areas such as general readability, working field extension and position, menu location and coherence, characters and colour. A team of researchers in Finland (Evreinova, Evreinov & Raisamo 2008) looked at alternative input devices, a camera joystick and a manual version, as part of ongoing work in this area. The efficacy of the devices for user input was compared in a target acquisition task, where neither the targets nor any pointers were available visually. The camera joystick is an arrangement where users point with their heads; more specifically, a template area of the face located near the eyebrows is tracked via a camera, so that aiming the area is used to move a virtual pointer around a grid to locate targets within that grid. For comparison, the same task was carried out using a manual joystick without force feedback. No visual feedback was available, only audio and haptic feedback. The idea is that the devices could be used for blind navigation in contexts such as game play and web navigation. It was clear from the results that users performed better with, and preferred, the camera joystick over the manual joystick. It was also clear however, that the haptic-perceptual space is very different from visual space, and solutions developed for blind users must take this into account.

Alternative interfaces were also the focus for a usability study (Fejtová, Figueiredo, Novák, Štěpánková & Gomes 2008) which looked at hands-free interaction. For users with limited or no use of arms and hands, touch-free interfaces offer considerable promise. In this paper, two new low-cost systems are described, both making use of the user’s eyes or nose movements to control the cursor. Both systems are in effect mouse emulators and therefore offer access to any mouse-controlled application. The process of using these alternatives was found to be rather slow, although this did improve over time, with the use of mouse-controlled toys being found to be helpful in building confidence and controlling home appliances. A similar focus was adopted by a group of Finnish and UK researchers (Istance, Hyrskykari, Vickers & Chaves 2009) who investigated multiplayer online role-playing groups, such as World of Warcraft, and the potential for interacting with these through eye gaze. Working with users with severe motor impairments, the researchers found that it was indeed feasible to carry out gameplay tasks at least at beginners level using eye-gaze alone.

Gaming was the focus too for work in Singapore on the development of psychotherapeutic games (Goh, Ang & Tan 2008). Although mostly a literature review to inform a project in its early stages, this paper also raises concerns about the limitations of existing work and indicates areas on which to focus in future. Games of a different kind were the focus in Finland, where a tactile memory game was developed for visually impaired children (Raisamo, Patomaki, Hasu & Pasto 2007). The researchers provided tactile memory games with multimodal navigation support and audio cues, so that users remembered different vibrations instead of sounds or embossed pictures. The response from users was positive, with the quality of the inexpensive gamepad used being deemed acceptable.

Some researchers have further developed the use of assistive technologies by children on the autism spectrum in order to enable learning where it was not previously possible. Using participatory design methodology, Cobb et al (2010) have explored two different collaborative interaction technologies: Collaborative Virtual Environments and Shared Active Surfaces. Working with typically developing children as well as those on the autism spectrum, Cobb and her colleagues in the COSPATIAL project have developed an integrated approach to develop learning scenarios in each technology, and their work continues. A different perspective on Collaborative Virtual Environments is provided by Cheng, Chiang and Cheng (2010) in their study of the use of these environments to develop and enhance empathy and the ability to take a particular perspective. It is the use of methodologies involving development alongside users and with their full participation that is often the hallmark of current research into technologies that enable learning.

Also involving working within a participatory design framework, but with a focus on providing inclusive education for a boy on the autism spectrum in Germany, is a case study based in a mainstream school classroom (Lingnau & Lenschow 2010). In this study, the researchers suggest the role of the enlightened teacher is vital, as is the emphasis on collaborative learning. Checkley et al (2010) took a different approach to participation, asking for children who use VOCAs to give their personal reactions to these technologies. The participants, three boys with autism, were clear that they found VOCA use to be pleasurable and motivating, these responses being obtained through using parents and school staff as expert guides. Participatory design comes with its own challenges of course, not least the challenge of objective measurement of the extent and validity of this involvement.
Again with a focus on learners on the Autism Spectrum in Nottingham – an area of impairment more researched than some others – a study of the use of interactive whiteboards (IWBs) again found potential provided that the teacher involved was clear about the aims and objectives of the technology use (Leach 2010). Key guidelines are provided for others who wish to explore the use of IWBs with this user group. IWBs are also involved as the delivery technology for software written with the needs of users with autism in mind: Reactickles (Keay-Bright 2008). Reporting on the first phase of development of the software, Keay-Bright explains how the project developed from earlier work in order to provide encouragement for social interaction and collaboration. Guldberg et al (2010) focussed on the development of social skills software for children with autism within the ECHOES II learning environment. The group once again found that the benefits of participatory design were clear, as was the complex nature of social intervention. Social intervention is a major area of research within autism and technologies, and the team developing the Collaborative Puzzle Game described above have continued to explore its potential (Battocchi et al 2010).

Researchers within Human-Computer Interaction (HCI) are well-represented within autism-related research, not surprising perhaps in view of the perceived interaction needs of this group of users. Conversation was the focus for a French project, which looked at two groups, those with autism and those developing typically, and their responses to a range of support modalities: text, speech and images (Grynszpan, Martin & Nadel 2008). After a series of structured interventions for both groups, the researchers found that those on the autism spectrum showed poorer performance on the richer multimedia interfaces, perhaps because they lacked the ability to organise the available range of modalities. The project team go on to address this perceived deficiency through the use of Animated Conversational Agents.

Some technologies with considerable potential are much less used than might have been expected. One such is predictive texting, long available through particular software tools but now much more widely familiar through mobile phone text. In a very useful overview and explanation of disambiguation, the principle on which predictive texting is based, Judge & Landeryou (2007) outline the considerable undeveloped potential for text entry, using these technologies and mobile phones, by those within the AAC community.

As has been described above, different modalities can assist in the accessibility of, for example, websites. The use of audio and image can be more than a support to those who struggle with text; these can in some cases enable access by a user who is unable to cope with text. This is the focus of work by Chen et al (2009), who looked at the effect of different support modalities on the reading of digital text. The researchers looked in particular at the needs of those with significant levels of developmental disabilities, such as severe learning difficulties or autism. Their conclusions include a call for flexible solutions, since they found that text-picture was the most suitable combination for students with autism, while those with learning difficulties were more supported by text-voice.

Robotics continues to develop its role as a discipline where there would seem to be considerable potential for current assistive technologies to be superseded or greatly enhanced. An EU project based at the University of Hertfordshire is working on the development of robot-assisted play (Robins et al 2010), with the robot playing the role of social mediator, encouraging children with special educational needs to discover a range of play styles, from solitary to collaborative play. The team also indicate the relevance of this work to a wider range of human-robot interactions.

Conclusion

Throughout this review, we note a move from a focus on technology to a focus on use and effectiveness. This has been enabled by rapid and multiple changes and developments in the technology itself, which has become cheaper, more easily available and more widespread. It is also, often, more effective, reliable and flexible. With all these developments, where AT and accessible products are becoming cheaper and more widely available, the situation described by Salminen (2008) has largely been superseded. The situation is complex, but User Centred Design takes into account context of use and the range of stakeholders concerned; and experimental design can meet that challenge (e.g., Brown et al, 2011b).

Most people now, including those with a disability, grow up with technology and expect it to do as they wish. Disability laws in many countries have spurred the development of products that are more useable and accessible. Design methodologies which include the users and other stakeholders have become more prominent in Human-Computer Interface research. Many new mainstream devices, such as the Wii, Kinect and
the Emotiv EPOC brain control device are more widely available and cheaper than in the past. Many different styles of interaction are available, and being trialled, by those with a disability and those with none.

It is clear that there are some key areas of development within current and recent assistive technologies research. Whilst recognising the relatively small number of papers and projects involved, we put forward the following as significant themes in the literature at present.

**User involvement**

A significant number of projects have acknowledged the need to involve users in the research which relates to them and their needs. The use of participant design approaches ensures that projects are less likely to be abandoned at a later stage, though this needs to be at a genuine and meaningful level. Levels of participation were identified by Hart (1992) with his Ladder of Young People’s Participation, ranging from tokenism and decoration (classified by Hart as non-participation) through information to shared decision-making.

**Mobile mainstream devices**

The rapid deployment and popular acceptance of mobile phones, particularly smartphone and other personal digital assistants, has led to an understandable demand for digital assistive technologies to be mediated through these devices. Products such as the Apple iPhone 4 and Windows 7 have good accessibility built in rather than there being a need to add it as an afterthought.

**Visibility of assistive technology use**

Assistive technologies have become much more visible, particularly as a result of the move of speech synthesis, speech recognition and graphic symbols into mainstream and inclusive settings.

**Interaction and collaboration**

Much of the research included in this review focuses on interaction between people with disabilities and, importantly, with those not identified as having disabilities. Interactional routes are multiplying and diversifying, as has been identified in the wider literature on multimodalities and changing literacies.

**Developing interfaces and technologies**

One of the few trends driven by technological advances rather than changing attitudes is the rapid development in alternative interfaces such as brain control, gesture control and eye-gaze. The use of robotics is another developing technological trend. It will be important that developing interfaces reflect young people’s experiences and expectations, for example of games controllers, as improving survival rates lead to more complex and multiple disabilities.

As can be seen from this series of emerging themes, almost all can be characterised as being part of the imperative to move from the special to the mainstream, from the medical to the social model and from adaptation to meeting the needs of all. Assistive technologies research is becoming ever more inclusive. In order to assess impact, however, we need longer term studies and for these to be led by teams who are independent from the developers of the technologies in question. The impact assessed should be that with regard to effectiveness for learning, so that it is not only rates of adoption and usability that come under this heading. Not only users and carers but also gatekeepers need to be involved in such research. No matter how inclusively and expertly designed the technology, if the gatekeepers (teachers, teaching assistants and therapists for example) are not trained in its use or sympathetic to it, the beneficiaries will never get the chance to use it. There are issues of classification to be dealt with here, and awareness and knowledge of products can be difficult to maintain in a rapidly changing field. However, European thematic networks such as ETNA and ATIS4All are providing online resources to address these issues.

Despite these moves, there is growing awareness of that version of the digital divide that affects those who may still not be fully included in society, due to learning difference or disability as well as socio-economic factors (McKenzie 2007). Noting that technology could form a mechanism for providing social capital, McKenzie goes on to state the continuing deficiencies in current society.

> ...people with learning disabilities generally still experience significant barriers to genuine social participation.
> ...[and] can be considered to be digitally excluded... IT can help [and can re-link the marginalised to their community]. However, there is still a distance to go before this goal can be achieved.

(McKenzie 2007: 21)
Charities such as the Children’s Society (Murray 2007) and MENCAP have been clear in their call for all children to access technology and online resources: the use of appropriate assistive and enabling technologies is one way in which this can begin to be achieved. It would seem likely that a key focus for assistive technologies researchers for the next few years should be continued consideration of the affordances of these technologies for bridging the digital divide, including all in life and learning, and minimising the “differentness” of assistive technologies. As we move beyond 2010 and the scope of this review, we welcome a renewed emphasis in the literature on access to assistive technology as a human right.

Assistive technologies are included among the [UN Convention on the Rights of Persons with Disabilities] measures to ensure three specific human rights. First, the right to freedom of expression and opinion and access to information should be ensured...

Second, to ensure the right to education, governments should facilitate learning of Braille and augmentative and alternative communication. They should also ensure that education is delivered using the most appropriate modes and means of communication.

Third, governments are required to facilitate the use of assistive technologies to ensure the right to participate in political and public life...

(Borg et al, 2011)

References


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W3C (2008b) How to Meet WCAG 2.0: A customizable quick reference to Web Content Accessibility Guidelines 2.0 requirements (success criteria) and techniques. www.w3.org/WAI/WCAG20/quickref/ accessed 27/2/09

W3C (2008c) Web Content Accessibility Guidelines (WCAG) 2.0. www.w3.org/TR/WCAG/ accessed 27/2/09


