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Medicine, Nursing and Health Sciences

ISCRR
Institute for Safety, Compensation and Recovery Research

Snapshot Review

Review of current and emerging assistive technologies for the reduction of care attendant hours: cost effectiveness, decision making tools and emerging practices

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Apps Master List	
Overview of Methods of studies	

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Executive Summary

Assistive Technologies (AT) is a rapid growth area to enhance participation, freedom from personal supports and enablement of self-determination for people with brain and spinal cord injuries. With the advent of new and emerging technologies – both mainstream and specialised there is limited evidence of the effectiveness of the technologies. Other areas that are lacking include appropriate assessment and evaluation of the technology, the person' performance with the technology as well as the economic implications of providing and supporting these technologies.

This project was driven by the above concerns by members of the TAC. There are increasing numbers of claims or requests for new and emerging technologies, and a decision making tool around assessing the credibility of claims is being developed by the sponsor. The purpose of this review was to scan the available literature, and provide a snapshot overview of the evidence available to help with this.

This was a 12 week iterative process, where the project sponsors and research staff spoke on a weekly basis to review the information and suggest future directions. What that means is that there is a large number of references gained and sourced but the quality of these articles has been measured in the most rudimentary way. Further, in depth review is required to add to the discussion here.

The literature was searched using a number of keywords. Databases, conference proceedings and grey literature were sourced, resulting in 457 articles, which were reduced to 203 in final analysis. The final analysis showed that the vast majority of papers were opinion pieces.

There were three research questions which have been addressed in the main body of the report. However, a fourth area – economic benefit or otherwise arose from the weekly meetings and the research literature. Thus we have included an economic analysis to help to put perspective on the results.

In summary, this report highlights the paucity of plausible literature in this field, and recommendations around this have been made. Of central importance is the workforce understanding their role in emergent technologies, longitudinal economic analysis of the effectiveness or otherwise of AT, and the need for robust but flexible outcome measurement in this field.

Background:

Assistive technologies (AT) are a rapidly developing area of practice for people with brain and spinal cord injuries, and the use of AT to ameliorate and enable people with disabilities to achieve participation in communication, community activities, self-care, productivity and leisure is constantly being updated. The most widely accepted definition of AT is that provided by the United States of America's Public Law (PL) 108-364 of the Assistive Technology Act (1998, amended 2004), which states that an assistive technology device is:

> "Any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customized that is used to increase, maintains or improve functional capabilities of individuals with disabilities' (as quoted in Cook & Polgar, 2008, p.5).

There are several important concepts in this definition. Firstly, an AT device can be any device, where the purpose is to assist an individual to participate in activities. This includes technology that is mainstream or used by all the population, mainstream technology that is modified and technology that is designed specifically for people with cognitive and/or physical impairments.

The context of this review is that there are increasing numbers of requests for assistive technology products from TAC clients. These technologies may be readily available in the consumer market, but increasingly new and emerging technologies are requested that have (a) a limited research evidence base for improved outcomes and (b) can result in additional and increasing costs, both for the equipment itself and the support required to use the technology, or (c) significantly reduce costs.

Models for provision of technology

Models of provision of AT are different between schemes, states and countries. Attempts have been made to standardise assistive technology services based on a common language and evidence base (Elsaesser & Bauer, 2011), but this remains problematic for two reasons. Firstly, the quality of evidence remains low, with much of the peer reviewed literature based on opinion. Secondly, the provision of emerging assistive technology remains inconsistent.

Difficulties receiving, maintaining and financing assistive technologies remain a common problem (Henschke, 2012; Hubbard Winkler et al., 2010). Additionally AT is so rapidly developing, that the workforce is often unprepared (Lewis, Cooper, Seelman, Cooper, & Schein, 2012).

Assistive Technology to Increase Independence

Previous definitions of independence are based around the notion of reduction in the need for personal care and increase in safety (Barbara and Curtain, 2008).

In 2011, the TAC introduced the 'independence model' for their clients with severe injuries (TAC, 2011). The liability for people with long term injuries was continuing to increase, together with increasing attendant care costs, non-measurement of client outcomes and plateauing of client satisfaction (TAC, 2011). The aims of the independence model are to ensure reasonable costs in long term, whilst enabling meaningful client outcomes.

The dictionary definition of independence states that independence is "freedom from the control, influence, support, aid or the like of others" (Dictionary.com, 2013). In terms of independence of people with disabilities, it is worth referencing two further sources – the UN convention on rights of persons with a disability (2008) and the productivity commission report on disability care and support (2011).

The productivity commission report on Disability Care and Support (2011) states that services aim to maximise people's independence and participation in the community. The commission uses the social model of disability health, and uses the concept of participation often interchangeably with independence. They describe the use of opportunities for people with disabilities to achieve potential for social independence. Social independence relies on the enablement of choice and innovation in all life areas including self-help, social skills, literacy and numeracy. To achieve this, they recommend facility and home-based activities, activities offered to the whole community as well as supervision and physical care.

To further the discussion of the meaning of independence, the UN Convention on the rights of persons with disabilities adopts a social model of disability. Their version of independence is full and effective participation in society on an equal basis with others (UN General Assembly., 2007). These concepts are more inclusive than previous definitions of independence, which focussed on personal assistance. However, in terms of measuring outcome, provide further difficulties.

Research Questions

This snapshot review has been conducted for the TAC to answer the following questions:

1. What is the effectiveness of low, medium and high assistive technologies in reducing attendant care hours? Evidence from aged care may be available and relevant for providing a basis.
2. What are the trends in the disability sector for emerging technologies such as i-Pad, i-Pod, smart, and tablet devices, in particular for people with ABI?
3. What are the emerging technologies reported?

Although the research questions were developed through negotiation at the commencement of the project, the process of this review was unusual, in that the process was an iterative discussion of articles and findings as they emerged. The reason for this was to ensure that the material sourced was that which met the sponsor's needs. This has resulted in a high number of articles, of varying quality. Quality assessment was performed only through examination of the methodology

Method

This is a snapshot review based on research questions developed using an iterative process between the researchers, TAC staff, and ISCRR. This review was not intended to provide an exhaustive search of the available literature; rather its intention was to provide an overview of the current and emerging trends in assistive technology (AT). Literature published between 2007 and 2013 was scanned and searched with regards to ABI, and SCI initially, but expanded to include literature from ageing research, dementia research and other developmental disability if the technology was relevant.

The search process was an iterative process, guided by weekly meetings between the sponsoring and research teams. Thus, research questions were expanded during the process to include different populations (aging, dementia and developmental disability) as well as excluding other articles (those relating to smart homes and robotics, except when specifically related to attendant care).

Quality was briefly assessed using only the methods used as described in the articles. This is not entirely robust. For example, McDonald et al (2011), used a randomised control trial methodology to compare the efficacy of electronic diaries with paper diaries for people with an acquired brain injury. Whilst the methodology was sound the trial consisted of only 12 participants, meaning that the generalizability of its results is low. However, this level of detail is beyond the scope of this review. Thus, systematic methodology of literature review was not possible and remains a limitation of the review.

Articles were selected for full scan/review based on their topic (i.e. being related to emerging technology, attendant care, reduction or measurement of attendant care hours, economic rationale). These were further excluded if not related to the final agreed terms.

The search strategy is described in further detail below.

SEARCH TERMS AND STRATEGY

1. **Database search:** Table one shows the search terms used.

Search Terms:

Assistive technology/devices	Smart technology	Electronic device
iPad/Tablet computer	iPhone/Mobile/Cell phone/Android/ Smartphone	Touchscreen
Communication device	Independence	Cognitive/memory aid
Quality of life	Emerging/new technology	Assistive technology trends
Apps/applications	Function/Functional independence	Access/Alternative access
ABI/TBI/brain injury	Attendant care/ Supported care	Cost effectiveness
Economics	Severe injury	Home/community-based care
Disability technology	SCI	ADL
Low/Med/High Assistive Technology devices	Aged care	AAC device/technology
Mobility	Aids and equipment	Disability
Electronic diaries	Intuitive technology	Universal design

Table 1: Search Terms

Searches:

Using the above keywords, both in singular and combination forms, databases were searched with the limits of year (2007 onwards) and English Language. Abstracts were scanned, and where the article met the criteria full texts were sought.

The databases searched included: CINAHL plus (159 articles), Medline (52 articles), Cochrane Database of Systematic Reviews (6 articles), Informit (12 articles), Taylor

and Francis (54 articles), PsychINFO (69 articles), Science Direct (91 articles), Sage (43 articles).

Hand Searching was completed for the following Journals: Disability and Rehabilitation: Assistive Technology (65 articles), Technology and Disability (45 articles), Augmentative and Alternative Communication (18 articles), Assistive Technology (37 articles), and Journal of Assistive Technologies (31 articles). Conference proceedings included Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) (22 articles), Australian Rehabilitation Assistive Technology Association (ARATA) (11 articles), Communication Matters (Comm Matters) (4 articles), Recent Advances in Assistive Technology and Engineering (RAate) (5 articles), Australian Group of Severe Communication Impairment (AGOSCI) (2 articles) and American Speech-Language Association (ASHA) (6 articles).

The references, together with copies of the articles, were uploaded into Endnote V6 database, and duplicates removed, resulting in 480 articles with abstracts reviewed. From these, a further 23 were removed resulting in 457 articles briefly reviewed in full.

The economic literature was sourced from 2000 onwards. This economic analysis was performed in addition to the research questions. Articles around the provision of economic rationale were sourced, read, reviewed, and synthesised.

Results

General Information:

This section has been divided into five separate sections: Sections 1, 2 and 3 will attempt to answer the research questions, divided into separate sections where relevant. Section 4 attempts to address the economic rationale for provision of AT. Section 5 outlines the potential barriers to use of AT.

Assistive technology potentially enhances wellbeing, enhances independence and enables people to live at home. Commonly available technologies enable people with ABI and SCI to compensate for difficulties performing daily living tasks(Larsson Lund, Lövgren-Egström, & Lexell, 2011; Larsson Lund, Lövgren Engström, & Lexell, 2012; Rigby, Ryan, & Campbell, 2011). The evidence however for new and emerging technologies remains scant.

Quality of Literature

The quality of the information sourced was generally poor, with the following breakdown: opinion (60 articles), review (19 articles), case study (47 articles), uncontrolled trial (59 articles), and controlled trial and systematic review (18 articles).

These results are consistent with the reported literature, that highlights that the majority of the research evidence is at the level of personal opinion, case study or uncontrolled study level, with small sample sizes (Antilla, Samuelsson, Salminen, & Brandt, 2012; Tai, Blain, & Chau, 2008). In terms of value for money, the potential impact with relatively low cost implications potentially make AT a cost effective intervention (Bamer, Connell, Dudgeon, & Johnson, 2010). However, it is difficult to separate optimism and enthusiasm for new technologies from evidence around the effectiveness of available AT. Evidence on the efficacy of AT needs to be investigated, and professionals who work in this field require knowledge and hands on experience (de Joode, van Boxtel, Verhey, & van Heugten, 2012).

The effectiveness of AT to reduce personal care is important, as people using more complex technology devices are more likely to also use formal care services (Agree, Freedman, Cornman, Wolf, & Marcotte, 2005). Cognitive deficits and low self-efficacy reduce the ability of people to use complex technologies (Alvseike & Bronnick, 2012). People with ABI require more mental effort, and take longer to complete tasks than the general population, but are often able to effectively use electronic devices to enable participation, either with or without supports (Boman, Rosenberg, Lundberg, & Nygard, 2012; Boman, Tham, Granqvist, Bartfai, & Hemmongsson, 2007; de Joode, van Boxtel, et al., 2012; Fish, Manly, Emslie, Evans, & Wilson, 2008).

The speed at which apps for mobile operating systems have become available is overtaking the speed at which users, clinicians and prescribers can keep up. Principles of matching the app and device to the needs of the consumer can often get lost (Gosnell, 2011; Gosnell, Costello, & Shane, 2011). Furthermore, much of

the technology is rapidly developing; for example, the use of iCloud for storage of information; use of iPad, iPhone and other devices as electronic controllers of AT (replacing traditional infra-red technologies); and, the use of these 'smart' technologies as safety and security devices. There were no articles identified on the use of these newer technologies.

1. **What is the effectiveness of low, medium and high assistive technologies in reducing attendant care hours? Evidence from aged care may be available and relevant for providing a basis.**

Personal Care and Independent Living

The capacity of equipment to substitute for, or supplement personal care has been a convincing argument, for some years (Agree & Freedman, 2011; Agree et al., 2005). Technology has been shown to have potential to improve quality of life (Agree & Freedman, 2011; Agree et al., 2005; Blaschke, Freddolino, & Mullen, 2009; Boman et al., 2007; Brandt & Alwin, 2012; Rigby et al., 2011), but the qualifications for this (especially in terms of participation) are not as clear. Consistently, assistive technologies such as environmental control units (ECUs) have been shown to decrease the need for personal assistance in certain populations – such as people living with spinal cord injury. This tends to be a reduction in care hours, rather than replacement (Hoenig, Taylor, & Sloan, 2003), although the reduction in care hours has been as dramatic as 2.5 times less than people who didn't use these devices (Rigby et al., 2011).

ECUs are reported to improve functional abilities and participation whilst reducing support needs (Brandt, Samuelsson, Töytäri, & Saliminen, 2011). Traditionally, these devices have worked on infra-red controllers, leading to a high level of abandonment. Infra-red devices are rapidly being replaced by wireless technologies used in mainstream society (e.g. in TV and music systems), which also, have the potential to be used to control the environment. The utility of iPads for easy access environmental control devices has been suggested (Alvseike & Bronnick, 2012). A simple ECU is built into the iPad as standard, with low cost accessories easy to purchase, use and install. What needs to be explored further is the potential for universal environmental control by iOS (iPhone/Pad operating system) or android technologies. Presently, there is little reference to this in the literature.

For people with cognitive impairment, software for enabling decision making around activities of daily livings, memory prompts, and structured decision making have been developed, but not robustly measured (Oldreive, Moore, & Waight, 2012).

Personal Care and Independent living from Aging literature

People aging with a disability have been found to have a slower decline in function when using AT and/or home modifications. Additionally, this group were also likely to use equipment to maintain independence in personal care activities (Wilson, Mitchell, Kemp, Adkins, & Mann, 2009). Sensors that detect moisture which are

connected to mobile technologies (hence, enabling freedom of community access or prevention of pressure ulcers) have been discussed, but not formally evaluated (Fernandes, Gaydecki, Jowitt, & van den Heuvel, 2011; Nijhof, van Gemert-Pijnen, de Jong, Ankoné, & Seydel, 2012).

CareTV shows promise at providing support through mainstream technologies (van den Heuvel, Jowitt, & McIntyre, 2012). CareTV is a concept where a person can set up reminders, interact with health professionals, and use a personal alarm through wireless or smart televisions. Traditional personal emergency response systems have been available for a long time, but their utility and availability has been scarce. Improvements in home monitoring systems show promise (Hessels, Le Prell, & Mann, 2011), but have been found to need specific practitioner expertise and alternative people (or hybrid) supports for environmental emergencies (King & Williams, 2008).

One issue, for people living with dementia, is the risk of wandering. This is also a risk for some people with ABI and cognitive impairments. Recent developments include using lower end, readily available technologies in new ways – such as using sleep monitors (actigraphs) to detect wandering; again these are ideas rather than proven interventions. Telecare monitoring has been shown to offer people an alternative means of support when they are unable to perform tasks for themselves (Cameron & Doughty, 2010). Telecare is inherently appealing for supporting people within their own homes, but often considerable support is needed to use them (Doughty, 2008; Doughty, Godfrey, & Mulvihill, 2012). Electronic surveillance and tracking techniques to monitor people at risk of wandering are continuously being developed, but practical and ethical issues remain (Hughes, 2008)

Memory Supports, Reminder aids and Electronic Diaries

Low cost strategies for memory aids such as a pager show promise to compensate for memory loss, but are not always sustained once input had ceased (Fish et al., 2008). Personal Digital Assistants (PDAs) have also been shown to have promise as a memory tool (Gentry, 2008), however, this technology is disappearing from the shelves and is being replaced by smart phone technologies. Other low cost technologies, such as a digital calendar with message board, have been found to support older people (Holthe & Walderhaug, 2010), but again, their use is not necessarily continued without support.

When looking at new and emerging technologies, television-assisted prompting (TAP) systems, (such as CareTV), encourages adherence to regimes, without a person having to leave their home (Lemoncello, Moore Sohlberg, Fickas, Albin, & Harn, 2011). When used with people with ABI, TAP has been shown to improve memory prompting, higher task completion and participation (Lemoncello, Sohlberg, Fickas, & Prideaux, 2011). Other home based electronic memory aids have been shown to assist the user to carry out activities in their own environments, however, additional supports are required for setting up and monitoring these (Boman, Bartfai, Borell, Tham, & Hemmingsson, 2010).

Studies specifically with people with ABI, have shown that reminder prompts and messages – through Telecare, other electronic devices or computerised promptings (e.g. calendar software) – are supportive of independence in personal care post inpatient rehabilitation (Boman et al., 2010; Boman et al., 2007; Costa & Doughty, 2009). However, people with ABI, do require training and multidisciplinary support to use these effectively (de Joode, Proot, van Heugten, Verhey, & van Boxtel, 2012; McDonald et al., 2011).

In a literature review of people with MS, electronic memory aids were not found to have sufficient evidence to support the effectiveness of memory rehabilitation; however, this was due to the limited quality of studies in the area (das Nair, Ferguson, Stark, & Lincoln, 2012). This remains the case with evidence for people with injury of a traumatic nature.

Access to and control technologies

New technologies are only useful for people with disabilities when they are able to access and control them. For example, touchscreen devices offer people direct access to a device, but the screens may be overly sensitive when used by people with motor impairments, such as spasticity. As technology develops, refinements to mainstream access continue to evolve.

Mainstream technologies are improving in their intuitive access (Chung, Beebe, Berends, & Hardcastle, 2012), thus, improving accessibility. Development of intelligent software alongside touchscreen technologies that can configure input devices for people with physical impairment by bypassing keyboards are reported (Horstmann Koester, Lopresti, & Simpson, 2007). Development of dampening techniques to improve input to desktop computers have been developed (such as tracker balls), and other dampening techniques are in development (Wobbrock & Myers, 2008). Experimental devices that show promise include making tiny intentional contraction of a single muscle to make an onscreen choice (Alves & Chau, 2011; Felzer, Beckerle, Rinderknecht, & Nordmann, 2010). An extension of this is the potential of brain computer interfaces (BCIs), via an interface such as an EEG, for people who have high level paralysis (Pasqualotto, Federici, & Belardinelli, 2012). One device – the EPOC neuroheadset – enables people to use their facial expression to control a computer. Its wider use by people with disabilities remains to be established (Lievesley, Wozencroft, & Ewins, 2011).

For people who are currently unable to access mainstream technologies, there is a body of reported case study work for individual solutions, such as sip and puff switches (Jones, Grogg, Anschultz, & Fierman, 2008), or speech/vocal driven systems (Judge, Robertson, Hawley, & Enderby, 2009; Judge, Robertson, & Hawley, 2011), or tongue input (Kencana & Heng, 2009; Lontis & Struijk, 2010; Mace,

Vaidyanathan, Wang, & Gupta, 2009). These access input devices tend to be one off devices, and their use with emerging technologies is not reported.

Other alternative access methods that show promise include eye gaze technologies (i.e. access via eye pointing on a computer screen) (Ball et al., 2010; Biswas & Langdon, 2011; Fager, Bardach, Russell, & Higginbotham, 2012; Najafi, Friday, & Robertson, 2008). For those who have eye conditions that compromise eye movement (e.g., nystagmus) eye-gaze technology may not be a viable option and head pointer devices may provide an alternative. A head pointer may be easier to use because it involves touching the pointer to the screen, but may not be as functional in terms of access to mainstream technologies as eye gaze (Fager, Bardach, et al., 2012; Fager, Jakobs, Beukelman, Ternus, & Schley, 2012; Kjeldsen, 2008).

Speech recognition technology traditionally excludes people with dysarthric speech, however, over time, they have become more useable by people with less clear speech (Young & Mihailidis, 2010). Voice activation of joysticks to enable access to computing and powered mobility are now at the stage of being comparable to regular joystick use (Harada, Landay, Malkin, Li, & Bilmes, 2008)

Mechanisms to enhance access –such as visual display for speech generating devices to improve the human-machine interface are reported (Wood Jackson, Wahlquist, & Marquis, 2011). Data gloves, where sensors detect the movement of hands and connect with a computer have been developed, but the high cost of sensor technologies make these prohibitive technologies at present (Tongrod, Lokavee, Watthanawisuth, Tuantranont, & Kerdcharoen, 2013).

When people are able to use their hands to operate technology, producing words via swipe or word prediction are useful ways of inputting text into an electronic device for people with ABI (Anson, Brandon, et al., 2012). Several methods can be used to make text more accessible such as replacing or augmenting a computer mouse or mouse cursor(Anson, Smith, & Hirschman, 2012; C. T. Shih, Shih, & Luo, 2011), integrating additional pointing devices, or utilising alternative computer inputs (C. H. Shih & Shih, 2010a, 2010b).

Enhancement of mobility

Mobility remains an area of high importance for people unable to walk independently, and the use of mobility aids often increases the need for attendant care. Increasingly, methods for enabling people with complex disabilities to independently acquire mobility are a focus of development. Development of intelligent wheelchairs (Zeng, Teo, Rebsamen, & Burdet, 2008), and those with anti-collision technology (Wang, Gorski, Holliday, & Fernie, 2011; Wang, Kontos, Holliday, & Fernie, 2011) are areas to watch for in the future. Hum-controlled wheelchair systems for people with motor and speech impairment (Falk, Andrews, Hotzé, Wan, & Chau, 2012), as well as wheelchairs controlled and navigated using a single switch (Ka, Simpson, &

Chung, 2012) are all presently in development. Using single switches to navigate in a wheelchair, with a laser rangefinder for safety has been developed and trialled with able bodied participants (Ka et al., 2012), but not people with disabilities.

Outcome measurement and decision making tools

In order to ensure that the person using AT has a good functional outcome, there are increasing numbers of evaluative tools. The use of the International Classification of Functioning, Disability and Health [ICF] (World Health Organisation [WHO], 2001) model is recommended (Steel & de Witte, 2011), in conjunction with effective analysis (Schraner, de Jonge, Layton, Bringolf, & Molenda, 2008). The ICF is internationally recognised as a good way of putting health and disability interventions into a measurable context. Tools being developed include: the User Testing Toolset (Woodcock, Fielden, & Bartlett, 2012); the Everyday Technology Use Questionnaire (ETUQ) (Hällgren, Nygård, & Kottorp, 2011); and, School-based Assessments for Children (Watson & Smith, 2012). Modified psychometric testing (Warschausky et al., 2012) is also a developing area.

Quality of life measures are important to researchers (Rigby et al., 2011), and are shown to be valid. The WHO disability Assessment Schedule 2 (WHO-DAS-II) has been recommended, and indeed improvements on the WHO-DAS II have been shown for people who are given assistive devices (Raggi, Albanesi, Gatti, Andrich, & Leonardi, 2010).

What is clear is that as technology is rapidly developing, the use of outcome measurement needs a great deal of further thought and investigation.

2. **What are the trends in the disability sector for emerging technologies such as i-pad, i-pod, smart, and tablet devices, in particular for people with ABI?**

Applications 'Apps'

There is limited evaluation of apps, but the promise of apps as memory devices, cognitive, and instructional aids to assist with record keeping, and as communication devices is rapidly developing (Sutton, 2012a, 2012b). As with other AT devices, involving users, at all levels, to judge success is crucial (Steele & Woronoff, 2011).

Built in features in mobile phones such as cameras, microphone, accelerometer, GPS receiver and touchscreens are useful and low cost supports for people with sensory difficulties, people with mental health problems, epilepsy, diabetes and communication issues. The potential for using apps for personal care, as a controller of home and environmental controls as well as health monitoring is only beginning to be realised. The literature in this space is nascent, especially when considering that the Apple iPhone was released in 2007, the Samsung Galaxy android system in 2010, and the Apple iPad in 2010. The majority of the information and evaluation of apps for people with disabilities tend to be web-based lists (such as www.janefarrell.com, or www.spectronicsinoz.com/article/iphoneipad-apps-for-aac). Some have attempted to rate these (Alliano, Herriger, Koutsofas, & Barlotta, 2012), but it is clear that there is such an explosion of information it is difficult to accurately assess and manage.

i-Pad and AAC

The price of many speech generating devices are a barrier to their purchase. However, using a mainstream tablet device has been embraced due to mainstream appearance, versatility and ease of supply (Slade, Massey-Westropp, & Stewert, 2012). The iPhone, iPod Touch and iPad, and their equivalent android technologies are becoming widely used as therapy tools in Speech and Language therapy, in particular due to their affordability, convenience and user friendliness (Fernandes, 2011).

Mobile devices and apps are replacing larger isolating Augmentative and Alternative Communication devices, as they are readily available, inexpensive compared to AAC devices and do not isolate the person (Atticks, 2012). However, the soft technology enablers of speech pathologists, occupational therapists and day-to-day support are still required (Shepherd, Campbell, Renzoni, & Sloan, 2009).

Recent developments stress the need for individual assessment to determine specific communication needs. The devices and apps available may not always be the best solution for people with complex communication needs, but show enormous promise (Bradshaw, 2013).

Mobile Phones

The potential of mobile phones is only just beginning to be realised. Barriers to the adoption of cell phones with older adults have been highlighted, due to two main reasons; one is the adoption of handset features (such as touchscreens) that are unfamiliar. The second main reason identified is the confusing nature of the mobile phone industry (Pedlow, Kasnitz, & Shuttleworth, 2010). This includes not only lack of access and understanding of features, but also difficult to access and understand menus and instructions of the telephone handsets themselves. For example, service handbooks are provided only in electronic means through the phone.

Nguyen et al (2007) identified barriers to use of mobile phone technologies for people with physical disabilities, including typing and control sites (Nguyen, Garrett, Downing, Walker, & Hobbs, 2007). Whilst some of these points remain relevant, there has been such a shift in mobile telephone technology, it is likely that the barriers currently experienced are different to those identified in 2007, but this is not presently published. Despite the usability of the current smart phone systems, for people with more complex physical impairments, smart phone access remains an area of great difficulty (Hreha & Snowdon, 2011).

When barriers are overcome however, there is the potential for smart phone technology (via iOS or android) to provide support for participation and everyday functioning. For instance, many new devices and systems incorporate virtual sensors in conjunction with GPS systems can generate alerts when a user travels out of range, or can measure potential falls (Doughty & Dunk, 2009). Calendar, contacts lists and mail are now all included as standard on all smart phones.

3. What are the emerging technologies reported?

Table 2 provides a snapshot of promising technologies reported in the literature.

Technology Area	Technologies reported
Access to and control of technology	• Eye gaze (continued advancements) (Ball et al., 2010; Biswas & Langdon, 2011; Fager, Bardach, et al., 2012; Najafi et al., 2008) • Trackball EdgeWrite (Wobbrock & Myers, 2008) • Experimental intentional muscle contraction switch system (Felzer et al., 2010) • EPOC neuroheadset (Lievesley et al., 2011) • Automatic speech recognition software (continued advancements) (Young & Mihailidis, 2010) • Voice-activated joystick (for computing and powered mobility)(Harada et al., 2008) • Microsoft Surface (Banes, 2009) • Data gloves (Tongrod et al., 2013) • Swype Input Method (for onscreen keyboard access) (Anson, Brandon, et al., 2012) • Intelligent software (Horstmann Koester et al., 2007)

	• Voice-activation software (Fager, Beukelman, Fried-Oken, Jakobs, & Baker, 2012; Judge et al., 2009)
Software/iDevice technology	• Google Calendar (McDonald et al., 2011) • iPad (for AAC, ECU control, and support with daily activities) (Alvseike & Bronnick, 2012; Atticks, 2012; Bradshaw, 2013; Rehabilitation Engineering Research Centre on Communication Enhancement [AAC-RERC], 2011) • Apps (for AAC and support with daily activities) (Alliano et al., 2012; Brainline, 2012; Doughty, 2011; Gosnell, 2011; Koehler, 2011) • Touch n'Tag (Konttila, Harjumaa, Muuraiskangas, Jokela, & Isomursu, 2012) • EqTD: Equivalent Text Description (Anson, Smith, et al., 2012) • Video phone (Boman et al., 2012) • Microsoft Windows7 on-screen keyboard (Chung et al., 2012) • Advances of the Android operating system (i.e. more accessible and capable of supporting AAC apps, etc.) (Higginbotham & Jacobs, 2011)
Mobility	• Intelligent wheelchairs (Zeng et al., 2008) • Wheelchair anti-collision technology (Wang, Kontos, et al., 2011) • Hum-drive wheelchairs (Falk et al., 2012) • Single-switch navigation (Ka et al., 2012) • Wearable power-assist locomotor device (Tanabe et al., 2013) • Autonavigating powered wheelchair (Bresler, 2012) • LWDAC: Lightweight durable adjustable composite wheelchair backrest
Support for independent living	• CareTV (van den Heuvel et al., 2012) • Activity monitoring systems (Price, 2007) • Service robots (Kent-Walsh & Binger, 2011) • Advanced integrated sensor networks (Bharucha et al., 2009) • Telecare monitoring systems (Cameron & Doughty, 2010; Doughty & Dunk, 2009) • Electronic incontinence pad sensor (Fernandes et al., 2011) • Actigraph (Nijhof et al., 2012)

Table 2: Snapshot of assistive technologies

4. Economic evaluation

According to Agree (Agree, 1999) the use of assistive technology differs significantly from the provision of personal care. Specifically, she notes that the application and use of assistive technologies does not demand ongoing involvement of other people (be they carers or care providers), and therefore, "increases the sense of independence with which a disabled individual can meet their long-term care needs." (p.427). It is clear that the use and application of such technologies will only become most cost-effective if there is improved prescribing of equipment and services (Dougherty, 2012); a point also noted by the Victorian Auditor General in their audit of individualised funding for disability services (Victorian Auditor General's Office [VAGO]. 2011).

In this report (2011), VAGO's recommendation 11 specifically notes that individualised funding (and thus the provision of tailored assistive technology solutions to people living with a disability) needs to be supported by through training and guidance, staff consistency and fairness in assessing Individual Support Package applications and allocating them and monitoring performance. The logic here is that greater 'control' is needed in assessing packages rather than control regarding what each package should contain. Thus, by better matching individual need to assistive technologies provided both allocative efficiency and maximum flexibility in responding to the needs of people living with a disability are optimised. Such an approach also helps to minimise (or potentially eliminate) waste while ensuring that the response provided "is not over-engineered as far as the risks to the individual are involved (Doughty et al., 2012)."

From a cost perspective, one study (Bamer et al., 2010) found that the cost of assistive technologies represent only 3.3% of the annual cost of care in people living with significantly disability (i.e. high assistive-technology needs). Dougherty (2012) concludes that while set up costs of assistive technologies may be high initially due to the cost associated with the acquisition of the assistive technologies, a longer term return is obtained due to fewer hours of support being required. Furthermore, in the case of people with poorer or unstable health conditions, Dougherty also concludes that savings can also obtained by the person living with a disability requiring less inpatient care as the technologies applied assist in keeping people healthy and in their own homes. Hoenig et al (2003) share this view; with their findings demonstrating that "technological assistance might substitute for at least some personal assistance in coping with disability."(p.335).

Specifically, people living with a disability who do not use assistive technologies report about four more hours of help per week compared with those who do use similar technologies. Furthermore, they note that their findings are consistent with accepted and current models of the disablement process given that contextual factors such as assistive technology actually modify the process and thus lessen the impact and the cost of disability.

By way of an estimate of economic gains achieved through the use of assistive technologies, it is fair to conclude that there is a relative paucity of cost-related studies that are applicable in the current study. That said the studies that are available generally examine costs associated with maintaining independence and leading a fulfilling life in aged care settings (Al-Oraibi, Fordham, & Lambert, 2012) research into the quantifiable gains in respect to health costs, it appears that the number of negative events (i.e. falls) is significantly reduced and the cost of care halved post incident when assistive technologies are employed.

Gains are not just possible in respect to fewer hours of support being required, as the Rehabilitation Engineering Research Centre on Communication Enhancement [RERCCE] (2011) have also identified that newer forms of assistive technology (i.e. smart phones, tablets, etc.) facilitate communication and social connection, both meaningful and appropriate outcomes for people living with a disability. As per VAGO's conclusions (VAGO, 2011), RERCCE also recognise the challenges associated with different forms of assessment being undertaken – with this potentially resulting in poor person-technology matches and/or over-engineered solutions being implemented. Given these factors, along with the pace of change inherent in such technologies, it is not surprising that RERCCE concluded that poorly designed and implemented systems could undermine third party insurers/funding (i.e. such as that from TAC).

In respect to electronic assistive technologies specifically, the literature is emergent rather than fully developed; meaning that little by way of longitudinal or adequately-controlled studies into the impact and cost of electronic assistive technologies exist. Fager et al (2012), for example, conclude that while access to electronic assistive technologies for people with severe physical disabilities is improving, most approaches that aim to create a systemic approach to their provision and use (i.e. to enhance uptake and use) do not meaningfully interface with the development of such technologies. This outcome, they suggest, represents a mismatch between actual use and the development cycles of such technologies. Furthermore, a mismatch can also be present when considering the impact of technology redundancy.

Redundancy from an assistive technology perspective most commonly means that the technology in question has been superseded or abandoned (Rehabilitation Engineering Research Centre on Communication Enhancement [AAC-RERC], 2011). When redundancy occurs, be that thorough the abandonment of a specific technology or the rapid replacement of existing technology, the literature suggests that funders should limit the range of options (rather than technologies) available while also actively managing the consumable aspects of such technologies (i.e. Internet access) (Andrich & Caracciolo, 2007; Rehabilitation Engineering Research Centre on Communication Enhancement [AAC-RERC], 2011)

The issue of on-going cost (i.e. the consumable aspects of electronic assistive technology use) is also of concern to funders and potential users, especially given

the potential cost to funders and/or users should users download large amounts of data. While this is an issue locally given the relatively higher cost of Internet access in Australia, this is not a phenomenon that is experienced internationally though; where, for example in the U.S.A. cost of Internet access was only an issue in 5% of a sample of 80 people living with ABI (Vaccaro, Hart, Whyte, & Buchhofer, 2007). Regardless, many emerging electronic assistive technologies require cabled and/or wireless Internet access in order to function as designed and required (e.g. using mapping applications on smart phones or tablets). Without equal access to such assistive technologies as well as to the Internet, people living with disabilities are potentially not maximising their civic, social and recreational participation (Bryen, Heake, Semenuk, & Segal, 2010; Vaccaro et al., 2007). Positive relationships have been detected between internet use and well-being for people with physical disabilities (Cheatham, 2012).

The notion of exclusion in respect to Internet access is receiving increasing attention, especially as it applies to at-risk or vulnerable communities (Blank, 2008). People in certain groups – such as people living with a disability, the aging, and people from low economic status backgrounds – are often excluded from using assistive and mainstream electronic technologies, either by technical or economic issues, or by the ability to learn how best to use the assistive technology (Baker & Moon, 2008; Vaccaro et al., 2007). People without Internet access have fewer opportunities and enjoy poorer social inclusion compared to those who can readily and easily access the Internet (Seale, 2011). Not surprisingly therefore, people living with ABI are often excluded from using the Internet, even when they do have access (Vaccaro et al., 2007).

Overall, it appears that a clear need exists for both cost and usage-related research remains; particularly research that is longitudinal and outcome rather than process-focused. This is particularly important as the literature suggests that it is possible to examine the relationship among cost, functioning and outcomes in respect to the prescribing and use of assistive technologies by examining the cost associated with not doing anything – namely, the opportunity cost of not providing assistive technology to people living with a disability (Schraner et al., 2008).

Conclusions and implications

The area of assistive technology is rapidly developing. This leads to exciting developments for people with disabilities in terms of accessing mainstream environments, enabling participation, potential reduction in attendant care and promotion of choice in self-care, productivity and leisure activities. However, this is a rapidly developing field with iPhone in existence since 2007, and iPad and android phones since 2010. The literature that has been developed tends to be opinion, development or idea, rather than rigorous evidence. There is little published literature on physical infrastructure of new devices, cloud technologies and their capabilities, security and safety.

1. Cost effectiveness of personal care technologies:
    - **a.** The most convincing, highest level evidence on reduction in personal care hours is around cost effectiveness of AT such as environmental control for people with physical impairments without associated cognitive impairments. Environmental Control Units are technologies that have existed for some years, and are generally well established. What is emerging though is the potential role of new and emerging technologies to take over from specialist ECU devices. Although many emerging iOS and android based phone and tablet systems have ECU potential, the physical and human interface access has yet to be determined.
    - **b.** Further research is indicated with (a) larger studies for the before mentioned group (b) studies on cost effectiveness, using appropriate methodologies for people with increasing levels of cognitive impairment.
2. Barriers to AT use
    - **a.** There are many barriers to AT use, both person based, services based and institution or service provider based.
    - **b.** One of the barriers to emerging (iOS, PC and Android programs and apps) is lack of internet access. It has been stated that people who do not have internet access are disadvantaged, particularly when this is required to access programs and applications. Furthermore, many programs and applications are only available by media such as iTunes, which require credit cards to activate. People with disabilities, alongside those who cannot physically access the internet are excluded from participation in mainstream society.
        - **i.** The increasing use of the internet in order to access common services (i.e. service system websites, school and learning information etc.) creates a potential barrier for people with disabilities if they are excluded from this. This concept should be explored further.

c. When there are physical and/or cognitive barriers to service, the use of providers of support (i.e. multidisciplinary assessment and intervention as well as personal supports) becomes essential. However, the best mechanisms to achieve this are not clear from the literature. Additionally, the workforce may not be familiar with the fast pace of the emerging technologies.

i. Outcome measurement of the effectiveness of different types of supports should be investigated. These outcome measurements need to be creatively developed to be robust, but accommodating of new technologies as they arise.

ii. Mechanisms to improve capacity of the workforce around technology should be considered.

iii. Further research on the cost effectiveness, number and type of teaching and training and the combination of these is an urgent topic for further research.

iv. Assessment and prescription information should be clear and directed, including supports and time estimated to learn and become competent in the device for the end user.

3. Access to technologies: Access to technologies remains one of the greatest barriers to using both every day and specialised technologies. People who have more complex impairments or combinations of impairments have greater difficulties with their access. Research tends to be reporting development or providing opinion, or based on single case studies. This can be enhanced in a number of ways.
    a. Building capacity in the health care workforce as to the range and breadth of access to input is essential
    b. Evaluation of access, as well as goal directed interventions should be provided and reported on where possible.
    c. Given small numbers of people and their supports, multicentre research and reporting is recommended.
    d. Cost effectiveness and longitudinal studies, even on a single case basis should be supported.
    e. Long term support for individuals is required from professional supports, even if to review mechanisms for accessing.
4. Memory supports: It appears that there is small but convincing evidence that the use of electronic aide memoirs is generally preferable to paper based systems. The automaticity of electronic devices – whether a phone, watch, Google calendar or others – provide multiple inputs that aid memory of the user. What is not clear is what the difference is between different supports.
5. iOS and Android technologies and AAC: The most convincing use of new technologies replacing specialised technologies is in the field of AAC. There remain several difficulties here. The specialised technologies work well for a population who have been using them for a considerable period of time, and

there is both maintenance and people support (soft technologies). On the other hand

   a. Continued research into the use of AAC and emerging technologies, and where the differentiation between specialised and other technologies is most useful.
   b. This is one area where controlled trials may be of some use. Given small numbers this would need to be a multicentre research project. Longitudinal studies, those which study quality of life and personal preferences are priorities.
   c. Development of workforce capacity is important – at both the support level as well as professional.

6. Smart phone technologies: Smart phone technologies have great potential, but access to them remains difficult. Additionally, the pace of smart phone technologies are so rapidly developing, that it is difficult to keep up with the pace of development.
   a. Policy, advocacy and advice regarding accessibility of mainstream smartphone technology at a policy and company level should be considered.
   b. Accessibility of information for people with print, audio, cognitive and physical difficulties should be mandatory at point of sale.
   c. Use of developing systems – such as GPS etc. – should continue to be investigated.
   d. Consider collaboration with manufacturers to help solve accessibility difficulties and use, as well as to realise the potential of these systems.
7. Personal care and Independent living
   a. The use of in home technologies, personal alarms in mobile phones, independent and care TV options as aid memoirs show great potential.
   b. Prospective research studies could be considered, which have specific aims of quantifying the influence of successful provision and training for people with disabilities to evaluate the effect on reduction of personal care hours (or not) as well as health and quality of life related factors.
8. Economic evaluation
   a. The literature around economic evaluation is emergent, rather than developed. Economic evaluation has tended to be short term, and further research is required in terms of longitudinal effects of assistive technology use on cost effectiveness, and efficacy.

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