Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IMPACT FACTOR: 6.017

IJCSMC, Vol. 8, Issue. 2, February 2019, pg.34 – 43

Mobile Devices and People with Learning Disabilities: A Literature Review

Peter Williams[1]; Sidharth Shekhar[2]

[1]Department of Information Studies, University College London, UK

[2]Department of Information Studies, University College London, UK

[1] peter.williams@ucl.ac.uk; [2] uczchek@ucl.ac.uk

Abstract— Background: Mobile technology is becoming ubiquitous. However, many usability problems present themselves in manipulating such devices - particularly for people with learning disabilities. A literature review was undertaken to determine factors affecting usability and how usability could be enhanced.

Method: Research literature on the usability of various mobile devices, with adults with intellectual, learning or cognitive disabilities was retrieved and examined.

Results: Differences in participant cohort; device type; research focus and methodology have precluded the development of an extensive body of evidence. Nevertheless, various problems were elicited, although almost no research has been undertaken on screen manipulation; interface design or aspects of menu organisation. Similarly, few suggestions are given on how devices could be made easier generally.

Conclusion: More research is needed in both the touch element of data and command input, and issues around interface design, and menu placement, length and hierarchy in a mobile environment.

Keywords— Mobile technology, smartphone, learning disabilities, intellectual disabilities, literature review

---

I. Introduction

Mobile technology is becoming ubiquitous. Statistica [1] reports, for example, that "over 28% of the world's total population owned a smart device in 2016 … expected to increase to 37% by 2020. In the same year smartphone penetration is set to reach 60.5 percent in North America as well as in Western Europe". In Australia, the smartphone penetration rate as a share of the total population is estimated to reach almost 75 percent by the year 2022. Despite this massive penetration, there are unique usability challenges with mobiles - These include small screen size, different display resolutions, device orientation changes and array of interaction methods such as tap, flick, and pinch – not to mention various 'unlock' mechanisms such as fingerprint recognition and shape forming by joining dots [2]. These challenges, of course, will be magnified for people with learning disabilities.

This paper examines research that has been undertaken to date in the area of mobile phone technology and people with learning disabilities, with a particular emphasis on the usability element of such devices. It begins with a discussion of the nature of mobile usability and the factors inherent in establishing the usability of mobile devices. It then examines the lack of an accumulated body of evidence around mobile usability for the cohort of people with learning disabilities in the area, and the reasons why this is the case. The usability studies are then described.

II. ACCESSING THE LITERATURE

Literature was restricted to academic journals found in the databases indexed in two university library electronic library services to which the author has access (University College London and The University of Hertfordshire). Both universities use a federated search system. In other words, they 'search different resources at the same time and then present the search results in a unified way' [3] obviating the needed to select different databases and search each separately. Searches were undertaken initially using different variations of the following search string:

("learning disab*" OR "intellectual disab*" OR "cognitive disab*") AND ((mobile OR "mobile phone" OR "smart phone" OR smartphone OR iphone OR i-phone OR tablet OR Laptop OR i-pad OR notebook)) AND (usab* OR access*)

From initial results accrued, chaining [4] was also undertaken. This is the practice of following citations *from* (backwards chaining) or *to* (forwards chaining) a relevant document. This method has also been described as 'citation tracking' [5] or 'ancestral searching' [6] in the learning disabilities literature

One main inclusion criterion was adopted. This was that only research about adult cohorts were considered, whose participants were described as having learning, cognitive or intellectual disabilities or difficulties (or with 'intellectual and developmental disabilities'). Studies were excluded, however, in which the participants were described as autistic (or on the 'autistic spectrum') unless they also were said to also have a learning disability. This is because only around half of people on this spectrum also have a learning disability [7].

There were no constraints on methodology (quite the reverse, one of the aims of the present paper is to explore methods chosen and any specific measures undertaken to take account possible difficulties or issues in undertaking academic study with the particular cohort). Similarly, no topic was excluded (e.g. regarding hardware or software etc.), as long as an element of usability formed part of the research. Literature reviews were also included (e.g. [8]) and more literature found by chaining these works.

In addition, literature was sought which addressed in general terms the issues inherent in evaluating mobile phone usability. The same search string (and variations) were used, but without any relating to the cohort under investigation. The term 'method*' was added for one search.

III. ASSESSING MOBILE PHONE USABILITY GENERALLY

All Before discussing individual studies around the cohort of people with learning disabilities, it is necessary to put such work into the general context of usability principles and practices, and the different factors inherent in the evaluation of mobile device usability. Regarding this, Nayebi, Desharnais and Abran [2] outline ways in which prior research studies evaluate and measure mobile device usability. They propose, from this literature, a general definition of usability for all types of software:

- More efficient to use (less time taken to complete any particular task)
- Easier to learn (operations can be learned through observation)
- More user satisfaction

The last point, 'user satisfaction' is used as a catch-all term that encompasses a variety of different stimuli that lead to a general feeling of subjective satisfaction by a mobile device user. This concept of user satisfaction is further broken down by several studies as consisting of a number of different components:

- Likeability: satisfaction of pragmatic goals – such as getting real-time directions using a mobile mapping service.
- Pleasure: satisfaction of hedonic goals – for example deriving viewing pleasure from an entertaining online video
- Comfort: physical satisfaction – such as the tactile pleasure derived from long hours of holding a well-designed, ergonomically-optimized mobile phone.
- Trust: satisfaction with security – such as the mental peace of mind derived from sending messages on a fully encrypted messaging service.

A key concept in usability is 'affordance'. According to Majchrzak et al.[9], an affordance is a 'mutuality of actor intentions and technology capabilities that provide the potential for a particular action' (p.38). In other words, it refers to the 'perceived and actual properties of an object that determine how the object could possibly be used' [10] (p.12). The design of an object has to be 'perceived' to be of use to the potential user. The classic example of an affordance is that of the door-knob which signals to the opener of the door whether to pull or to push [11]. In terms of interface design, Pettit [12] gives the example of a 'Submit' area on a web page, arguing that it looks less like an interactive feature if it is simply a word, than if it contained a border. It is more likely to be perceived as a clickable area, however, if it included a virtual 3 dimensional 'button'. Examples of simple affordances in Information Technology are abundant – raised buttons on a keyboard to signify that they can be pressed, the colour red and the letter 'X' used in tandem to signify closing an application or window, the tiny magnifying glass icon placed next to many search bars across the internet – to signify "searching" for something.

Schrock [13] introduces the term 'Communicative Affordances' which according to him 'describe the relationship between subjective perception of utility and objective qualities of a technology that results in altered communication and subsequent patterns of behaviour' (pp. 1239). He specifically formulates a typology for communicative affordance of mobile media and communication, by breaking it down into the following categories:

- Portability – the physical characteristics of a device (size, weight etc.) that comprise this attribute.
- Availability – how available an individual is through mobile media to their contacts, from notifications of messages, to sounds and vibrations from calls.
- Locatability – The usage of GPS to signal one's location through a variety of mobile applications.
- Multimediality – The presence of front and back cameras to signal the possibility to capture images and video.

Benedito et. al [14] emphasize the importance of tactile affordances, especially – of course - with regard to blind users, stating that typical screen reading software is often inadequate as a mechanism of receiving full feedback from the device. They state that the slight tactile vibration when elements are pressed on the mobile touch-screen – and especially relevant when interacting with the keypad – is an essential affordance for blind users to fully interact and utilize their mobile devices. Recent (unpublished) work by the present writer suggests that such a facility may help people with learning disabilities too, in having a physical guide to help locate required keys and centralise one's touch.

Both Apple [15] and Google [16], the primary mobile device software manufacturers (of the iOS and Android operating systems respectively) have set their own user interface guidelines which guide developers to consider several usability characteristics when creating their applications. These include considerations for displays with different resolutions and dimensions, device orientation changes, variation in touch gestures (such as tap, pinch, and flick), and the size and location of buttons and icons, the size and format of text and contextual menus.

IV. USABILITY STUDIES INVOLVING PEOPLE WITH LEARNING DISABILITIES

A. Introduction: The Lack of an Accumulated Body of Knowledge

The Before examining empirical research that has been carried out in the area, it is worth exploring an issue prevalent in other aspects of digital technology and people with learning disabilities. This is the fragmented and wide-ranging research literature, because of which there is no extensive body of work built up examining any particular aspect of the subject. Differences in studies conspiring against building up a body of empirical evidence in the area of mobile technology include:

- Participant cohort
- Device type
- Area of interest
- Methodology

These are discussed in turn below.

Participant cohort: This problem is partly due to terminology. For example, participants have been described as having (or being with):

- 'mild to moderate intellectual disabilities' [17], which the authors define as having a reading age and primary level of education as 'preschool';
- 'cognitive disabilities', undefined [18] but which 'varied across functional, physical, and social dimensions' (p180) and whose participants were profiled individually;
- 'intellectual disabilities' [19], again, undefined, but also with individual profiles;
- Down Syndrome, where the degree of learning disability may be undefined (e.g. [20]) despite the fact that the degree of learning disability varies amongst this cohort [21], [22]
- mild communication or cognitive limitation combined with mobility difficulties [23]

- Autism [24], [25]. As mentioned, this condition need not result in a learning disability, and therefore research with this cohort is not reported here.

Device type: Even with regard to 'mobile' devices, a huge variety of alternative hardware can be studied. With regard to people with learning disabilities, these have included:

- iPads (e.g. [20])
- 'electronic tablet' (plus participants' own devices)[23]
- 'mobile phones' [18]
- 'smartphones' [26].

Adding more complication is the fact that the technology advances so rapidly, that studies undertaken more than a few years ago do not apply to a contemporary climate. For example, Dawe's [18] study of 'mobile phones' which, although acknowledging features such as cameras and web browsers, discussed only calling and texting, without commenting on other features - even in terms of non-use. Only the fact that 'mobile phones are becoming smaller ... and simultaneously packing more functionality into a reduced screen' was mentioned, which the authors add led to 'a complex user interface … tiny buttons, and a complex navigation system [which] make phone use difficult for a person who is unable to read or does not have fine motor control' (Ibid: p180).

Area of interest: There is an extremely wide variation in research focus, even when considering only the 'usability' aspect of mobile devices. These include:

- Examining 'global' usage of the technology (i.e. different functionalities within a device):
  - In a naturalistic day-to-day basis, and the usability problems encountered therein (Dawe, [18], as mentioned)
  - To facilitate a particular activity [19];
  - As a suite of particular tasks [17], [20];
  - Assessing the efficacy of particular apps [27]

Methodology: These have included:

- Formal usability tests with target user groups [17]
- Automatic comparison of metrics comparing PC versus mobile rendering of pages [28]
- Qualitative interviews with users [18]
- Case study ethnographic approaches[19].

An attempt at a review of the literature by Cáliz, [8], illustrates both its paucity and the fragmentary nature illustrated above, albeit being focused only on people with Down Syndrome. The authors point out that, despite their article being entitled 'Usability testing in mobile applications …', they 'have not found any significant efforts considering mobile applications and people with DS' (pp8-9). The research that was reviewed included work that was merely 'useful to extract information about usability testing' (p.5) with the cohort. Examples included a paper on an 'Augmented Reality basic reading courseware' presented on a tablet [29]; the evaluation of a literacy programme - actually, as the authors of the cited paper state, residing in a fixed 'rugged, custom-designed kiosks' [30] (p2) rather than on a mobile device, and various other studies unrelated to mobile technology (e.g. employing methods to explore the usefulness of using WCAG as a heuristic for website accessibility [31]).

B. Empirical Studies

Title Given the diversity outlined above, the following represents an indicative summary of the research available relating to mobile devices and people with learning disabilities. Interestingly, the literature does not deal explicitly with the factors outlined above (efficiency, ease of use, satisfaction, likeability, trust or affordance) and does not tend to examine features that are specific to mobile devices – in particular the touch-screen interactive element of tapping, swiping and other movements acting as commands.

Beginning with formal usability testing, Kumin et al [20] explored the usability of touch-screen displays and virtual keyboards on a 'multi-touch tablet computer', with people with Down Syndrome. The authors list skills required to use 'computers'. Although the list was regarding this cohort, it could also apply to people with general learning disabilities or, indeed, anyone at all. The skills listed were 'fine motor skills, visual-motor skills, visual memory skills, letter recognition skills, [and] reading and literacy skills,' (p.118). Where applicable, the research literature described below is mapped onto these skills.

Participants fulfilled several criteria including being 18 or over; with the Trisomy 21 form of Down syndrome (the most prevalent form for 95% of the population); having previous experience with computers and the Internet and 'basic experience' with touch-screen computers. Each performed a series of tasks in five different categories on an iPad. These were divided into 'five categories of tasks that are typically important for computer usage in the workplace … social networking, email, calendaring/scheduling, price comparison, and basic text entry/note-taking'. The specific tasks included:

- typing in a URL,
- finding contacts, and adding a contact,
- sending an email,
- finding the date of the World Down Syndrome Day (an entry in the calendar),
- comparing prices of a particular book on various book-selling sites,
- Inputting a short paragraph of text.

Although some of the skills listed to use computers (fine motor, visual-motor, visual memory, etc.) can be mapped onto either the specific tasks (such as typing aa URL requiring letter recognition and literacy skills); or to how the tasks were undertaken (were visual motor skills exhibited whilst negotiating a menu, for example) this was not undertaken.

In addition to observation (in which participants were encouraged but not given any help with the tasks) the time taken to complete tasks was recorded, and participants completed a Likert Scale of their assessment of task-difficulty. This consisted of 5 points, from very easy to very difficult.

Results showed that 'all participants were able to complete the majority of the tasks in all five categories [although] … performance varied dramatically' (p.136). 'Some' participants had problems with the touch-screen (as it was very sensitive) and often accidentally tapped and therefore activated unwanted icons, or closed windows or applications in the middle of a task. Participants also had problems with icons, partly because they were unfamiliar with them, and partly because they were 'small ... often unrecognizable … and often cryptic' (p137).

Problems with passwords were also noted. This was explained by the supposition that passwords are often saved on participants' own computers so that they do not need to be keyed in after the first occasion (in the test condition they had to enter their Facebook password, for example, whereas at home this may be pre-entered). Interestingly, participants 'had no problems when they encountered visual CAPTCHAs'. The article makes clear that people with Down Syndrome have what the author termed 'visual strengths', which might explain this ability.

One aspect of user behaviour manifested was the extensive use of 'search features'. Several examples are given although it is not quite clear what this behaviour entailed. For example, one participant 'first searched the Facebook Web site using Google. Then she used the search feature in Facebook to find the NDSC [National Down Syndrome Congress] page' (p137). It may be that the participant searched Google to find the Facebook site, and then within Facebook to find the organisation. Similarly, 'participants also used the search function extensively in order to complete the calendar tasks and the price comparison tasks' (p.137). This was, presumably, a surprise to the researchers, as they had supplied the relevant URLs. Doing a search on 'Facebook' seems to be hardly less of an effort than writing www.facebook.com. By contrast, other users were unable to find a search box (such as in a book selling site) when it was needed to find a product. Recommendations can be summarised as offering greater training for the cohort 'includ[ing] formal classes to learn to use tablet computers' (p.138)

Rocha, Bessa and Cabral [17] also assessed the efficacy of an iPad (a 'mini' iPad, as described, although this was not defined), and also by formal usability testing. They examined usability in terms of tasks related to what they described as 'selection', 'manipulation', and 'insertion', by people with 'intellectual disabilities' (ID). Twenty people participated in the study, aged between 19 to 44 years, with 'mild to moderate ID'. Findings were compared to an earlier study by the same lead author [32].

Participants were required to carry out five tasks, although these were far different to those formulated by Kumin et al [20]. In this case, the tasks were around adding colour to a line drawing and three manipulating 'pieces' of a puzzle. In brief, the tasks broken down individually were:

- 'Task 1 - Selection: participants had to …select [a] color (sic) and [then] tint the drawing area
- Task 2 – Selection and Manipulation: … drag the colour to tint the drawing area.
- Task 3 – Manipulation: … make two puzzles using … touch and drag. First, they had to select the piece of the puzzle ([by] touch) and then … drag the piece to link the right place on the composition.

- Task 4 – Selection and Manipulation: … a game … using touch action. This game consists in grouping colorful globes, touching three different buttons (left and right and fire). The player wins when there are no globes left.
- Task 5 – Selection and Insertion: … three searches in YouTube website. … They first had to recognize the search field and touch it to start writing [given] keyword[s] (previously shown to them and written in a paper) [and] click the search button or press enter.' (p3)

Tasks were performed randomly, and no help was offered unless requested (although there is no indication about who availed themselves of this and the extent to which help was given). The study measured effectiveness, efficiency and satisfaction. These were defined as:

- Effectiveness: performing the tasks without giving up
- Efficiency (also termed 'resources spent'): time to conclude the task, errors made and difficulties observed
- Satisfaction: comfort and acceptance of the work within the system.

Results revealed that, according to the authors' definition of 'effectiveness', all participants completed the tasks, though eight did not do so successfully on Task Four. No-one gave up. As for 'efficiency' some difficulties were noted in 'selecting the drawing areas with one touch regarding the pressure needed to perform this movement'. Fewer participants had difficulties in dragging virtual pieces, but those who did lost their piece 'many times'. For one of the tasks (3) an unstated number of participants 'had difficulties positioning the hand on the mini iPad' (p.4). Although these difficulties are not explained, they appear to relate to fine-motor and visual-motor skills.

For tasks four and five, results are compared to the earlier study where a keyboard and mouse were used (only the former is required for task four). Participants (again, the number is not stated) 'had many difficulties in writing the keywords with the keyboard', but not with the touch-screen. These difficulties consisted of 'continuously click[ing] on a key and frequently confus[ing] the right and left mouse buttons (problems noted by the present writer in a study of the usability of game activities for people with learning disabilities[33]. These problems seem to relate more to a cognitive impairment presenting a barrier to task understanding rather than motor skills, or even literacy limitations (with regard to the latter, the problem was not spelling or letter identification on the keyboard).

Task time was substantially quicker on the touchscreen, and fewer errors were recorded. This 'seemed to happen because with the physical keyboard they have to divide their attention [between] … the keyboard input device and output device (monitor), they cannot make a direct manipulation of the information that is possible with the mini iPad' (p5). There is an element of visual-motor co-ordination here, in co-ordinating the gaze between the keyboard and monitor and the physical actions required to input text and control the curser.

Hoehl and Lewis [28] examined only the user interface but, rather than work with actual or potential users, undertook an automated test, which considered 'a number of metrics for the pages retrieved … including file size and character/word/sentence counts for both the page source as well as the content that would be seen by users of the page' (p263). The websites chosen for analysis were simply a selection of the most visited websites in the United States. The researchers explored 'the potential benefits of using mobile webpages to present simpler web content to people with cognitive disabilities', although in fact the authors merely compared different metrics (as described above) of desktop and mobile-rendered web pages, concluding that 'Mobile sites provide less content to users and can benefit those with cognitive … disabilities by offering a simpler presentation of web content'.

A small amount of usability testing concentrating on particular applications (or 'apps') has also been undertaken. For example, Auger et al [23] examined the usability of two mobile 'apps' designed to aid shopping tasks for people with 'physical disabilities [and] mild communication or cognitive limitations' (p12777). Two pre-existing apps were chosen by the research team ('whose expertise covers rehabilitation technologies') using 'five dimensions based on the team's judgement: user-friendliness, content, psychometric properties, applicability and other considerations …. [such as] 'strategies put in place to make the application more appealing and easy to use' (pp. 12779 / 12794). The apps chosen were 'AbleRoad' and 'Jaccede', which – although varying in detail – both enable users to upload their own reviews of 'service establishments' (shops, restaurants etc.) in terms of accessibility, and/or read others' reviews.

Research participants were required to access reviews and compare them with their own experiences of the locations evaluated. Data were gathered by pre- and post-test interviews, with the latter being aided by participant photos taken during the shopping visits. Lewis's [34], [35] *After-Scenario Questionnaire* and *Post-Study Systems Usability Questionnaire* were used in the questioning.

Usability results suggested that participants liked large text, both for 'easier reading' and as it 'made the application more appealing'. The vocabulary was sometimes difficult (e.g., "multi-level access", "visual guidance disposal", "threshold" …) 'Mobile applications were easy to use and to manipulate when the buttons' size was appropriate' (although what 'appropriate' meant was not explained) and 'when there was a limited number of steps to obtain the desired information'. Finding the shops evaluated was 'more difficult' (though how was not explained) 'especially when the geolocation function did not work' (pp.12786-12787). The use of various different rating scales was confusing (dichotomous [yes/no], nominal, ordinal, numerical and ratio scales were all used). In short, usability issues centred around 'choice of language, store location, number of steps required to access information (and how it is presented), and the types of scale used to evaluate accessibility.

Other papers evaluating specific apps include the use of a smart phone and QR codes for users to access and follow interactive guides to help them with everyday tasks such as making breakfast [36]; using an app to aid travel autonomy[27]; and a 'multimodal intervention and tool to increase the adherence to a physical activity' [26]. There is also, of course, substantial literature examining learning generally with iPads and/or mobile apps [24], [37].

Other work around mobile technology and learning disabilities has not looked exclusively at usability, although that aspect has formed part of such studies. Dawe[18], for example, 'conducted … interviews with five families to understand he current patterns of remote communication among young adults with cognitive disabilities and their parental caregivers, and the role that remote communication played in increasing independence and safety' (p179). Inclusion criteria were 'the ability to perform coarse motor operations on a handheld device, and sufficient social and functional skills to perform tasks away from a caregiver' (p.180). Being carried out in (or prior to) 2007, this research is, in IT terms, quite dated as it was carried out prior to the era of internet-enabled smartphones.

Three of the families had mobile phones, which they claimed, 'was a central communication media between all members of the family.' (p180). People with cognitive disabilities initiated many of the calls, with one major reason cited as the need to resolve an unexpected situation, such as missing a bus'. A thriving social network between care-givers was also noted, including 'case managers, job coaches, places of employment … friends and other family members [and] bus drivers' (p182).

The interview schedule did not appear to include anything on usability – exploring instead 'current remote communication methods, purposes and tools [and in] … increasing perceptions of safety and independence … [and] if and how parents monitored their child's activities' (p180). Nevertheless, the authors report various usability issues that arose during the study. Difficulties included negotiating confusing menus (thus making access to features such as the address book and voicemail difficult), using small keypads and 'the fine manual dexterity required to plug in the charger' (p183). Various design recommendations were made:

- 'Large, customizable picture-based buttons could replace small number-based buttons. …
- 'Simplified accessible voicemail ….
- 'A simplified interface to the phone's digital camera [which] could enable the user to share location and contextual information with a caregiver' (p185 [bullet format added to replace original table])

More recently, Cumming et al [19] looked at the use of an iPad to support people with intellectual disabilities as researchers – specifically to 'enable them to participate in the research in a more equitable manner' (p.1000) – on a wider study exploring the well-being of ageing women with intellectual disabilities and their self-reported satisfaction with their lives. 'Researchers' (i.e. study participants) were given a 15-week (90 minutes per week) training programme to use the iPads. Activities included how to take notes (presumably using a touch-screen keyboard); take, store and retrieve photos, and prepare presentations. The level of disability was not specified, but this appears to have been mild, considering the activities undertaken.

The research was qualitative, with only four participants, and results presented as detailed case studies of each of the four. The use of the technology was not as successful as the authors would no doubt have liked. One participant, for example, 'decided that using an iPad did not provide her with any tangible benefits' (p1010). Many of the problems of using a touch screen appear to have been the result of poor motor skills (or to 'long fingernails' in one case), making almost all actions very difficult. A stylus was offered as a solution but rejected. Also related to motor skills was the problem of charging the devices. Here, difficulties were reported in manipulating the plug to fit the socket.

A completely different problem was that of the appropriation of the device. On being asked whether she was happy with her iPad at home, one of the participants revealed that a 'one of the staff members came in one day, … took it away from the cupboard and … gave it to somebody …. I never saw it again' (p1007). The researchers retrieved the device and returned it. Although no other details of this case are given (beyond the fact that the authors retrieved the device for her) it is worth mentioning here what Goodley [38] (p442) describes as the 'untouchable expert authority'. This is where those surrounding the person with disabilities (or is otherwise vulnerable) feel that the best course of action is to take responsibility for their charges without involving them in the decision-making process.

More positively, much benefit was accrued from the iPads. Although they were used to facilitate the participation of these women in research, 'in practice the major benefit was to their quality of life'. Participants enjoyed photographing their 'social network'. These gave 'concrete cues for conversation. By using the iPad's camera, [one of the participants] became more interesting to her carers, who then spent more time interacting with her' (p1010). Participants also liked playing games on their iPads, and all four 'commented several times on their learning preferences, needs, and opportunities [and] often mentioned that they are learning more than ever before' (p1010). This 'learning' appears to be principally in terms of learning the iPad itself and the accompanying terminology, although one of the participants requested 'apps that had information about animals [and] several animal and encyclopaedia applications [were] installed on it' (p1006). She also requested 'apps' on The Blue Mountains and other historical places of interest.

Some work has also been undertaken on children's use of mobile technology. Carlson [39] examined the effects of incorporating iPad tablets (incorporating audio modelling by a recorded fluent speaker) to aid reading comprehension for 7 – 10-year olds with learning disabilities. This resulted in 'moderate improvements' in reading. More broadly, and more with autistic people in focus, Allen, Hartley, and Cain [24] discuss the use of educational and recreational apps, and 'outline recommendations for the use of electronic tablets and the design features for apps to promote learning in this population' (p1305).

V. CONCLUSIONS

This paper has examined the literature on usability aspects of mobile phone use by people with learning disabilities. It began with an outline of what are generally considered to be the main principles and practices, before outlining why there does not appear to be a coherent body of research evidence around the issue. This seems to be due to the diversity of cohort, device type, area of study and methodology.

Tentative findings from the limited amount of existing research suggest that touch screens present problems of size and sensitivity [20] as does 'positioning hands on a mini-iPad' [17] (p4); remembering passwords and finding search boxes. In a rare study including consideration of keyboard types, Rocha, Bessa and Cabral, [17] it appeared that a mini-iPad virtual keyboard is easier to manipulate than a physical keyboard connected to a PC – not because the former was easier to use, per se, but because a physical keyboard is remote from the screen and so divides attention. Surprisingly, very little research appears to have been undertaken on screen manipulation – the actions of tapping, swiping or pinching [40] – although Rocha, Bessa and Cabral [17] examined tasks requiring participants to drag and select (by tapping), noting problems regarding the ability to drag a virtual object round a screen and the pressure needed in tapping.

Perhaps in keeping with the lack of a rigorous and cumulative body of research, findings from the limited research undertaken make very few suggestions as to how devices could be made easier. only larger 'buttons' (virtual, one assumes), a simplified interface[18], more training [20] and simpler vocabulary [23] being prominent. More research is clearly needed in both the touch element of data and command input, and issues around menu placement, length and hierarchy in a mobile environment. There is virtually nothing in the literature on this – only Kumin et al, [20] remark that 'drop-down' menus were difficult for their cohort of adults with Down syndrome to navigate. If ever there was a case of 'more research is needed', clearly, in this case, it is!

ACKNOWLEDGEMENT

The study reported here is part of a programme of research being generously funded by The British Academy as a Post-doctoral Fellowship awarded to Pete Williams, who would also like to thank his steering group, Prof. Barrie Gunter, Dr Andrew MacFarlane, Dr Mina Vasalou and Dr Rob Miller, for their invaluable help and advice throughout the project.

REFERENCES

[1] Statistica *Number of smartphones sold to end users worldwide from 2007 to 2017 (in million units)* 2018a, Available at: https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/ (accessed 21.02.18)
[2] F. Nayebi, J. Desharnais, A. Abran, The state of the art of mobile application usability evaluation. In *Electrical & Computer Engineering (CCECE), 2012 25th IEEE Canadian Conference* 2012, pp.1-4.
[3] Y. Wang, J. Mi, J. Searchability and discoverability of library resources: Federated search and beyond. *College & Undergraduate Libraries*, 2012, 19(2-4), 229-245.
[4] D. Ellis, A Behavioural Model for Information Retrieval System Design *Journal of Information Science,* 1989, 15(4/5) pp. 237-247.
[5] S. Caton, M. Chapman, The use of social media and people with intellectual disability: A systematic review and thematic analysis, *Journal of Intellectual and Developmental Disability*, 2016, 41(2) pp.125-139
[6] D. Kagohara, and 10 others, Using iPods and iPads in teaching programs for individuals with developmental disabilities: A systematic review. *Research in Developmental Disabilities*, 2013, 34(1), pp.147–156.
[7] E. Frombonne, S. Quirke, A. Hagan, Epidemiology of Pervasive Developmental Disorders In D. G. Amaral, G. Dawson, D. H. Geschwind, *Autism spectrum disorders* New York, NY 2011, pp. 90–111
[8] D. Cáliz, L. Martínez, X. Alamán, C. Terán, R. Cáliz, Usability Testing In Mobile Applications Involving People With Down Syndrome: A Literature Review", *Computer Science & Information Technology,* 2016 6(7) pp. 1-11.
[9] A. Majchrzak, S. Faraj, G. Kane, B. Azad, The contradictory influence of social media affordances on online communal knowledge sharing. *Journal of Computer-Mediated Communication*, 2013, 19(1), 38–55.
[10] D. Shin, The role of affordance in the experience of virtual reality learning: Technological and affective affordances in virtual reality. *Telematics and Informatics*, 2017, 32(2), 1e12
[11] D. Norman, *The design of everyday things: Revised and expanded edition*. New York, NY: Basic Books, 2013.
[12] N, Pettit, *What Are Affordances in Web Design?* Available at: http://blog.teamtreehouse.com/affordances-web-design 2014, (accessed 04.01.18)
[13] A. Schrock,. Communicative affordances of mobile media: Portability, availability, locatability, and multimediality. *International Journal of Communication*, 2015, 9, pp.1229–1246
[14] J. Benedito, T. Guerreiro, H. Nicolau, D. Gonçalves, D., The key role of touch in non-visual mobile interaction. In *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services Lisbon, Portugal.* Sep 2010. ACM pp. 379-380.
[15] Apple.com (2017) Human Interface Guidelines Available at: https://developer.apple.com/ios/human-interface-guidelines/overview/themes/ (Accessed 21.12.17)
[16] Android.com, *User Interface Guidelines* Available at: https://developer.android.com/guide/practices/ui_guidelines/index.html (Accessed 21.12.17)
[17] T. Rocha, M. Bessa, L. Cabral, Performing universal tasks using a mini iPad: usability assessment per people with intellectual disabilities. *Proceedings of the XVII International Conference on human computer interaction* 2016, pp.1–6.
[18] M. Dawe, Understanding mobile phone requirements for young adults with cognitive disabilities. In *Proceedings of the 9th international ACM SIGACCESS conference on Computers and accessibility (Assets '07).* ACM, New York, NY, USA, 2017, pp.179-186.
[19] T. Cumming, et al. Mobile technology in inclusive research: tools of empowerment. *Disability & Society*, 2014, pp.1–14.
[20] L. Kumin, J. Lazar, J. Feng, N. Ekedebe, N. A Usability Evaluation of Workplace-Related Tasks on a Multi-Touch Tablet Computer by Adults with Down Syndrome *Journal of Usability Studies* 2012, 7(4) pp. 118–142
[21] A. Chitty, V. Dawson, V. *Down's Syndrome: The Essential Guide* 2013 Peterborough: Need2Know books
[22] Mencap, *Down's Syndrome* Available at https://www.mencap.org.uk/learning-disability-explained/conditions/downs-syndrome (accessed 26.02.18)

[23] C, Auger, C. Leduc, D. Labbé, C. Guay, B. Fillion, C. Bottari, B. Swaine, B. Mobile applications for participation at the shopping mall: content analysis and usability for persons with physical disabilities and communication or cognitive limitations", *International journal of environmental research and public health* 2014, 11(12) pp. 12777-12794.

[24] M. Allen, C. Hartley, and K. Cain, iPads and the Use of "Apps" by Children with Autism Spectrum Disorder: Do They Promote Learning? *Frontiers in psychology, 2016,* 7, pp. 1305.

[25] Khan, S., Tahir, A. Raza, Usability issues for smartphone users with special needs – Autism *International Conference on Open Source Systems and Technologies*, Lahore 2013, pp. 107-113

[26] D. Pérez-Cruzado, A. Cuesta-Vargas, Improving Adherence Physical Activity with a Smartphone Application Based on Adults with Intellectual Disabilities (APPCOID)", *BMC public health*, 2013, 13(1), pp. 1173-1173.

[27] E. Landeros-Dugourd, *Quasi-experimental study: DCog and travel autonomy for young adults with cognitive disabilities*. Ph.D. thesis, Capella University, Minneapolis, MN. Available at: https://www.learntechlib.org/p/123198/ (accessed 14.02.19).

[28] J. Hoehl, C. Lewis, Mobile web on the desktop: simpler web browsing *Proceedings of the 13th international ACM SIGACCESS conference on computers and accessibility* New York: ACM, 2011, pp. 263-264.

[29] R. Ramli, H. Zaman, Designing usability evaluation methodology framework of Augmented Reality basic reading courseware (AR BACA SindD) for Down Syndrome learner. *Proceedings of the 2011 International Conference on Electrical Engineering and Informatics*, 2011, pp.1-5.

[30] F. Adebesin, P. Kotzé, and H. Gelderblom, The complementary role of two evaluation methods in the usability and accessibility evaluation of a non-standard system. *Proceedings of the 2010 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists*, 2010 pp.1–11.

[31] D. Rømen, D. Svanæs, Validating WCAG versions 1.0 and 2.0 through usability testing with disabled users. Universal Access in the Information Society, 2012, 11(4), pp.375-385.

[32] T. Rocha, M. Bessa, L. Magalhães, L. Cabral, L. Performing universal tasks on the Web: interaction with digital content by people with intellectual disabilities. In: *XVI International Conference on HCI* (interáccion 2015) (Vilanova i la Geltrú, Spain, September 7-9, 2015). Interáccion 2015 Proceedings, ACM New York, NY, USA, 2015.

[33] P. Williams, D. Nicholas, Testing the usability of information technology applications with learners with special educational needs *Journal of Research in Special Educational Needs* 2006, 6(1) pp31-41

[34] J. Lewis, Psychometric evaluation of an after-scenario questionnaire for computer usability studies: The ASQ. *Proc. SIGCHI Conference of Human Factors in Computing Systems* 1991, 23, pp.71–81.

[35] J. Lewis, Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ. *Proc. SIGCHI Conference of Human Factors in Computing Systems* 1992, 36, pp.1259–1260

[36] X. Gómez, G. Alamán, J. Montoro, C. Torrado, A. Plaza, AmICog – mobile technologies to assist people with cognitive disabilities in the work place. *ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal*, 2013, 2(7), pp.9–17.

[37] S. Papavasiliou, M, Saridaki, C. Mourlas, C. K. Van Isacker, Providing Assistive ICT Learning for People with Disabilities through a Personalised Mobile Application, IEEE, 2014, pp. 592.

[38] D. Goodley, Supporting people with learning difficulties in self-advocacy groups and models of disability.. *Health and Social Care in the Community*, 1998, 6(6), 438-446.

[39] K. Carlson,. *Incorporating IPad® Mobile Digital Devices within Repeated Reading Interventions for Students with Learning Disabilities,* Doctoral Thesis, University of South Dakota, 2014.

[40] C. Stößel, L. Blessing, L. Tap, swipe & pinch: Designing suitable multi-touch gestures for older users 2010 *Proceedings of the 11th International DESIGN Conference Dubrovnik, Croatia: Design Society* pp. 463-472.