

A systematic review of personal smart technologies used to improve outcomes in adults with acquired brain injuries

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Abstract

Objective: This review aimed to determine the effectiveness of personal smart technologies on outcomes in adults with acquired brain injury.

Data sources: A systematic literature search was conducted on 30 May 2019. Twelve electronic databases, grey literature databases, PROSPERO, reference list and author citations were searched.

Methods: Randomised controlled trials were included if personal smart technology was used to improve independence, goal attainment/function, fatigue or quality of life in adults with acquired brain injury. Data were extracted using a bespoke form and the TIDieR checklist. Studies were graded using the PEDro scale to assess quality of reporting. Meta-analysis was conducted across four studies.

Results: Six studies met the inclusion criteria, generating a total of 244 participants. All studies were of high quality (PEDro ≥ 6). Interventions included personal digital assistant, smartphone app, mobile phone messaging, Neuropage and an iPad. Reporting of intervention tailoring for individual needs was inconsistent. All studies measured goal attainment/function but none measured independence or fatigue. One study ($n=42$) reported a significant increase in memory-specific goal attainment ($p=0.0001$) and retrospective memory function ($p=0.042$) in favour of the intervention. Another study ($n=8$) reported a significant increase in social participation in favour of the intervention ($p=0.01$). However, our meta-analyses found no significant effect of personal smart technology on goal attainment, cognitive or psychological function.

Conclusion: At present, there is insufficient evidence to support the clinical benefit of personal smart technologies to improve outcomes in acquired brain injury. Researchers need to conduct more randomised studies to evaluate these interventions and measure their potential effects/harms.

Keywords

Brain injury, systematic review, activities of daily living, stroke, assistive electronic technologies

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Introduction

Smart electronic technologies have been proposed as one solution to the problems associated with independent living faced by people with acquired brain injury, but their effectiveness needs to be established before they are recommended. Acquired brain injury is a term used to describe non-progressive damage to the brain which occurs after birth and has sudden onset.¹ The long-term nature and often life-changing consequences of acquired brain injury mean that significant social and economic burden is placed on patients, families and healthcare resources. 'Personal smart technology' may benefit acquired brain injury survivors, enabling them to lead more independent and fulfilling lives. We define personal smart technology in this review as an electronic device that can be used interactively to serve a particular function and aid everyday activities, which is small enough to carry about/on the person.

Although many technologies exist to aid cognition and facilitate physical rehabilitation, there appears to be limited personal smart technology available to improve or maintain independence and functional outcomes for people with acquired brain injury. There are currently several personal smart technologies (e.g. mobile phones and tablets) available to support the heterogenous nature of acquired brain injury, with the ability to aid multiple symptoms and facilitate independent living. These are used in some clinical settings, but evidence for the effectiveness of such interventions to improve independence and functional outcomes in adults with acquired brain injury has yet to be systematically evaluated. Therefore, it is timely to conduct this review to highlight the level of evidence available for the effectiveness of personal smart technologies.

This review's primary aims were to determine the effectiveness of personal smart technology compared to usual care or other types of intervention, on the independence, functional outcomes, fatigue and quality of life of adults with acquired brain injury. The secondary aims were to assess use and satisfaction of the intervention; impact on cognitive, psychological and social functioning, or

participation; and any other benefits or harms associated with technology use.

Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines² and the protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO 2016 CRD42016050717). Twelve electronic databases were searched from inception to 30 May 2019 (Supplemental Appendix 1). Grey literature searches were conducted using Google, Google Scholar, the British Library Catalogue, PsycExtra, Mednar, CORE (CONnecting REpositories), and theses searches (using British Library EThOS theses online, DART-Europe E-theses Portal and Networked Digital Library of Theses and Dissertations). Citations for the authors of included studies were undertaken.

We developed a search strategy using indexed terms and words relating to acquired brain injury, personal smart technology, and functional outcomes and independence (Supplemental Appendix 2). To minimise retrieval bias, we did not restrict our search by date. The search strategy was adapted to the requirements of the databases searched. Search results were exported directly to EndNote X8 and duplicates removed. Additional identified records were manually added.

Studies reporting data from adults (aged 18 and above) who sustained an acquired brain injury (traumatic brain injury, stroke, haemorrhage, anoxia, infection, brain tumours or mixed acquired brain injury) were included. We included all relevant randomised controlled trials (RCTs), including cross-over RCTs but only extracted the precrossover study data, and quasi-randomised studies were excluded. Studies delivering personal smart technology interventions, defined as an intervention using an electronic device or system (small and portable, for example, a smartphone, tablet or personal digital assistant that can be used interactively to serve a particular function) were included. We included studies measuring at least one of our primary outcomes of interest: independence,

function (i.e. things that are meaningful to a patient in the context of everyday living and refers to an integrated series of behaviours or skills that allows the patient to achieve important everyday goals), fatigue or quality of life. The secondary outcomes of interest were as follows: use and satisfaction of the intervention, psychological functioning (including mood, self-esteem, anxiety and self-efficacy), social functioning or participation and any other benefits or harms of technology use.

One author independently inspected the searches, and relevant abstracts were identified; two authors then independently inspected all abstracts (50% each). One author inspected and identified full-texts meeting inclusion criteria. A second author inspected 10% of these to ensure accuracy. Three authors independently assessed quality of included studies using the PEDro scale.³

Data were extracted relating to aspects of study design, participant characteristics, details of the intervention, outcome measures (primary and secondary) and conclusions (see Supplemental Appendix 4). One author developed and used a bespoke data extraction form, which was modelled on the Template for Intervention Description and Replication (TIDieR) checklist⁴ to extract data from the included studies.

Meta-analysis was conducted on outcomes of interest where data were available. Data from each study were pooled using a random-effects model, as this takes into account study sample size and the estimate of between-study variation when weighting study effects. If a study reported more than one measure of a specific outcome, we chose the measure that was most similar to those used by the other studies or the one that provided a global measure of function. To avoid bias, this was decided ahead of the quantitative data extraction. Where high scores represented a poor outcome, the valence of the score was changed from positive to negative. Standardised mean difference (SMD) was used as a summary statistic, as various outcome measures were used by the studies. Meta-analytic means were expressed with 95% confidence intervals (CIs). All analyses were performed using Review Manager (RevMan, version 5.3).⁵

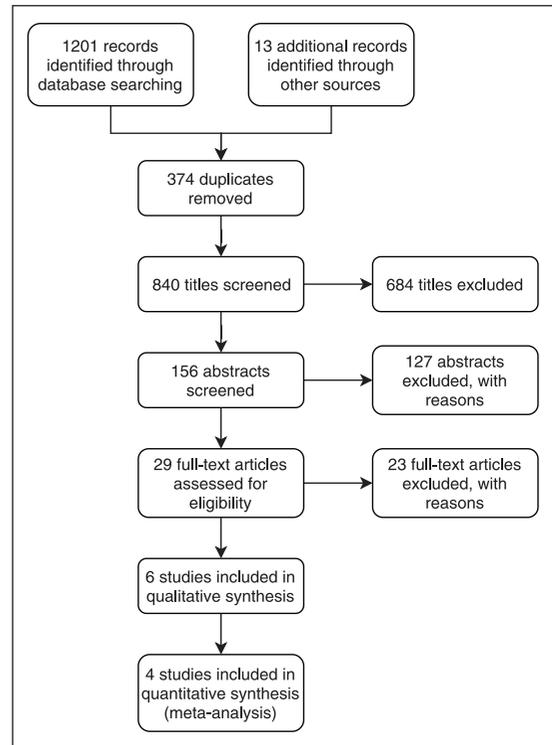


Figure 1. PRISMA flow diagram of study selection process.

Results

Six studies were included in the review. Figure 1 presents a PRISMA flow diagram. Reasons for exclusion are presented in Supplemental Appendix 3. The reviewers were in full agreement regarding which studies met the inclusion criteria. All six studies were of high quality (≥ 6) according to the PEDro scale (Supplemental Appendix 4). A total of 244 people with acquired brain injury were recruited and randomised across the studies. Five studies used a parallel group design⁶⁻¹⁰ and one a crossover design¹¹ (Supplemental Appendix 5). Only one study⁷ recruited people exclusively on an inpatient basis, and the remainder recruited from several settings. Dropout rates (range: 0%–20%) were recorded for all studies. The intervention period varied for the studies, lasting between three and eight weeks.

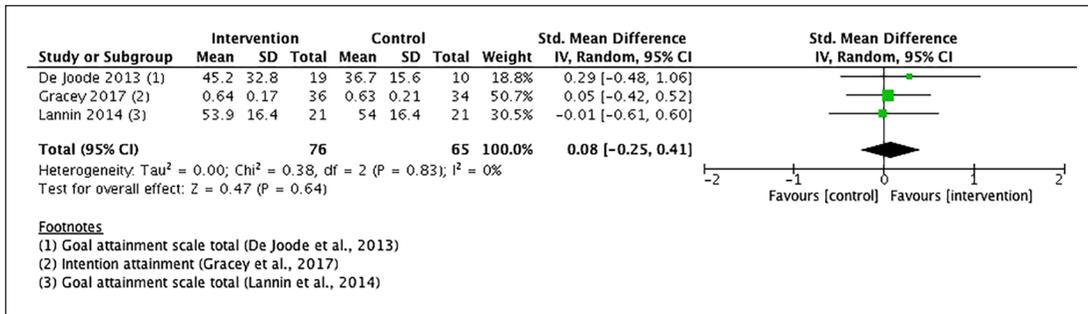


Figure 2. Meta-analysis of goal (or intention) attainment outcome measures for three studies.

For each study, the box represents the random-effects standardised mean difference and the line the 95% confidence intervals. The size of each box indicates the relative weight of each study in the meta-analysis.

All studies described their interventions sufficiently well to be compliant with the TIDieR checklist.⁴ They used different types of personal smart technology (Supplemental Appendix 6): planning system on a personal digital assistant,¹⁰ metronome smartphone application for stroke patients,⁷ paging device called Neuropage,¹¹ standard mobile phone⁸ text messages and an iPad tablet⁹ for home exercises. Four of the interventions^{6,8,10,11} focused on goal-directed tasks. The control groups varied between studies. Two studies^{6,7} provided the control group with ‘care as usual’ or ‘conventional therapy’. The remaining studies provided alternative interventions, including educational training, paper-based diary and non-intervention-based text messages.

A therapist delivered the intervention training in five studies.^{6,8–11} Training duration for the participants varied between studies, with the majority delivering multiple 30 minute sessions. Intervention fidelity was not addressed by any of the studies, meaning there was no reference to whether the intervention was delivered as intended and if this was assessed.

All six studies assessed functional outcomes, defined as things that are meaningful to the patient in the context of everyday living. Interestingly, none of the studies used specific measures of independence or fatigue.

One study¹⁰ ($n=42$) using goal-attainment scaling to measure memory-specific failure goals in the context of daily living, reported a significant improvement in the intervention group at eightweeks compared to the control (mean

difference: 1.6, 95% CI: 1.0–2.2, $p=0.0001$) (Supplemental Appendix 7). For the remaining studies, no significant improvement in goal attainment was reported in favour of the intervention. In our meta-analysis (Figure 2), we found no significant effect of the intervention on goal attainment.

Three studies^{6,8,11} used at least one measure of psychological function, assessing self-efficacy and depression, mood state, and anxiety and depression (Supplemental Appendix 8). However, no significant improvement was found in favour of the interventions. Our meta-analysis (Figure 3) also demonstrated no significant effect of the intervention on psychological function.

Two studies^{6,10} used at least one measure of cognitive function. One study¹⁰ ($n=42$) presented Memory Functioning Questionnaire scores in two categories: retrospective memory functioning and mnemonic usage subset. A significant difference in retrospective memory scores was found ($p=0.042$), meaning the intervention group had a greater improvement in retrospective memory ability compared to the control group. However, our meta-analysis (Figure 4) showed no significant effect of the intervention on cognitive function.

One study⁸ ($n=8$) measured social participation and function using three different subsets of the Participation Assessment with Recombined Tools-Objective: social relations, out and about, and productivity. At eightweeks’ post-intervention, the ‘social relations’ scores significantly improved in the intervention group compared to the control group ($p=0.01$).

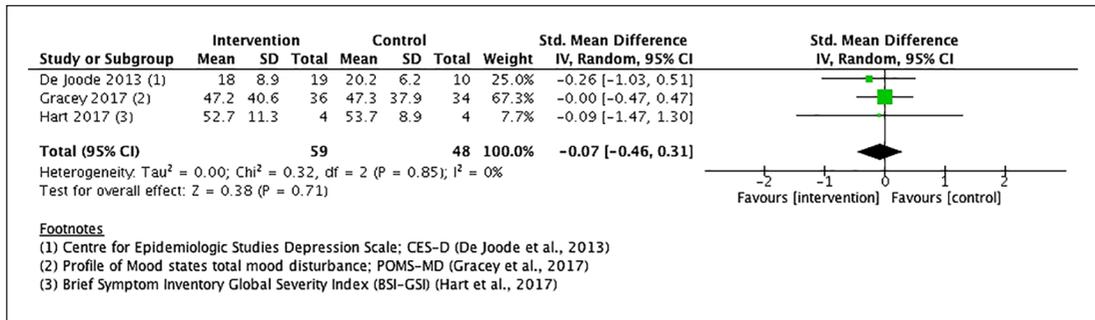


Figure 3. Meta-analysis of psychological function for three studies.

For each study, the box represents the random-effects standardised mean difference and the line the 95% confidence intervals. The size of each box indicates the relative weight of each study in the meta-analysis.

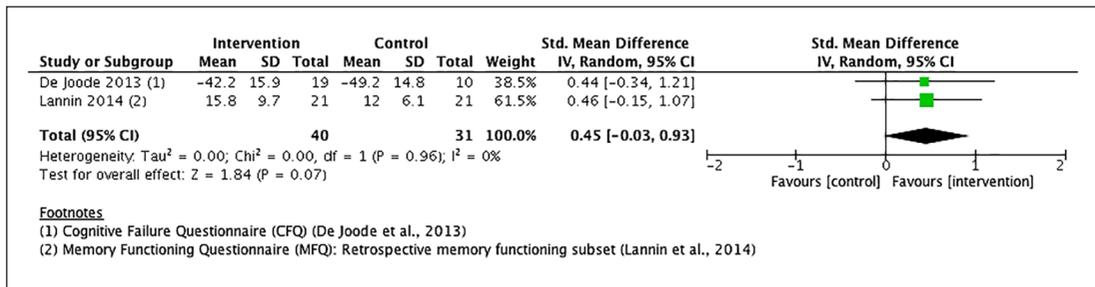


Figure 4. Meta-analysis of cognitive function for two studies.

For each study, the box represents the random-effects standardised mean difference and the line the 95% confidence intervals. The size of each box indicates the relative weight of each study in the meta-analysis.

Three studies^{6,9,10} assessed satisfaction with the intervention by asking participants whether they would continue use, reasons for this, whether they were satisfied with their allocated group, and one⁹ study assessed the participants' perceptions of the intervention. Some studies reported a greater percentage of satisfaction in the intervention group; however, this was not significantly different to the control group.

Discussion

The review identified six studies that focused on function and each used a different technology intervention. Although one study suggested a use for personal smart technologies to improve memory-specific goals and memory impairment and another to increase social participation, there is

a clear lack of robust evidence to support the clinical recommendation of these technologies in acquired brain injury. There are very few randomised studies investigating such technologies, and most interventions have only been evaluated once. There is also a lack of studies exploring the effects of personal smart technologies on independence and fatigue. Given the ubiquity of technology in modern society, specifically smartphones, it was interesting to find that only one study evaluated a smartphone application and only one used mobile phone text messaging.

Although all studies scored high on quality, the PEDro scale does not take into account power/sample size calculations. Only two studies^{10,11} conducted power calculations prior to recruitment, one⁶ conducted a post-hoc calculation, which suggested insufficient power to detect treatment effect.

Most studies had a small number of participants, ranging from 8 to 74. Perhaps a disadvantage of small sample trials is that it may not be possible to perform further analyses to determine who benefits the most from the use of personal smart technologies, and under what circumstances. Pre–post analysis is not always recommended in RCTs and was a limitation of some of the included studies.¹² This highlights the need for larger sample, high-quality studies within this area of research.

While most studies were compliant with the TIDieR checklist when reporting interventions (e.g. dose, content and training), few reported how and if the technologies were tailored to individual needs.

Studies have identified the importance of patient-centred technology in the acquired brain injury population,^{13,14} meaning personalisation of interventions should be reported better in future studies to facilitate replication and improve intervention design. The TIDieR checklist⁴ helped us detail the interventions consistently and highlighted areas of reporting that need more attention. We recommend that researchers make use of this and other checklists (e.g. Journal Article Reporting Standards checklist¹⁵) when detailing interventions.

Outcome measures varied between studies, but all presented measures of goal attainment and/or function. Although some studies presented significant outcome improvement for the intervention groups, these findings should be treated with caution, as evidence is limited; thus, we are unable to suggest a clear benefit of these technologies for acquired brain injury. Indeed, our meta-analysis found no evidence of the overall effectiveness of the intervention.

Only one study specifically reported on whether or not there were any serious adverse events or harms caused by the use of personal smart technologies. This is something that future studies should assess and report.

Despite the focus on goal attainment and function, few other effects of personal smart technology were explored. None of the studies reported measures of independence with only one study measuring quality of life and one reporting social participation outcomes. None of the studies

reported measures of fatigue. Literature identifies these as some of the more challenging problems to clinically manage following acquired brain injury (specifically fatigue),^{16,17} so it was disappointing to find no high-quality studies exploring these outcomes. Improving social participation and quality of life are often the key foci of rehabilitation interventions¹⁸ and are increasingly being recommended as the primary outcomes from funders such as the National Institute for Health Research (UK). However, it appears that these outcomes are not receiving enough attention in research studies. Researchers need to consider the long-term implementation of their interventions when choosing outcome measures and place more emphasis on the invisible sequelae of acquired brain injury, that are often more difficult to manage, such as fatigue and mood problems. Our findings resonate with the findings from a 2015 review by Charters et al.,¹⁹ which also identified a lack of studies evaluating the effect of technology on the greater needs of the acquired brain injury population. This highlights the need for larger RCTs with a focus on different needs of the brain injury population.

A key strength of this review was the use of the TIDieR checklist to extract information across the different technologies about their key components and potential factors that contribute to their effectiveness (e.g. training, procedures and frequency of use). The guidelines aided our data extraction, and facilitated consistent collection and description of the technologies. The rapid advances in technology and drivers for self-management following acquired brain injury mean that new technologies are emerging all the time. Without understanding and reporting the core components of interventions, and transferring information about factors impacting on their effectiveness, technologists will miss these key findings.

While this review had robust methodology and used a systematic search strategy to identify relevant trials, it does have limitations. We limited our search to English language only, which may have excluded some relevant studies. We also applied tight inclusion criteria to studies not measuring at least one of our primary outcomes of interest (i.e. functional outcomes, quality of life, independence

and fatigue). This led to the exclusion of some interesting studies reporting the use of smartphone-based interventions, such as SMS symptom assessment for mild traumatic brain injury,²⁰ which used the Rivermead Post-concussion Symptoms Questionnaire.^{20,21} Most studies used a cognitive measure as their primary outcome. We suggest altering the study-selection criteria in future reviews to exclude certain technologies and focus on those targeting specific problems, for example, memory impairment and fatigue management. Another limitation is that we did not include people with progressive neurological disorders, such as multiple sclerosis, that experience similar cognitive manifestations (e.g. difficulties with problem-solving, remembering tasks and concentrating).

There is insufficient high-quality evidence to support the benefit of personal smart technologies to improve outcomes in acquired brain injury. As the UK National Health Service Five Year Forward view²² is pushing for greater self-management for people with long-term conditions, there is a timely need to explore the effectiveness of everyday smart technologies to support rehabilitation. To move the field forward, we need researchers to conduct more randomised studies to evaluate technologies. Researchers also need to describe interventions better (including tailoring and personalisation), ensure intervention delivery and uptake are accurately recorded and that outcomes focus on both symptom reduction as well as independence and function. Future studies should also report on the barriers to implementation and measure the potential effects and harms of technologies, which are often under-reported.

Clinical messages

- There is a lack of evidence to support the benefit of personal smart technologies to improve outcomes in acquired brain injury.
- There are few randomised studies investigating these technologies, and most of them have only been evaluated once.
- Adverse effects of smart technologies are potentially under-reported.

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Author contributions

Literature searches and data extraction was conducted by J.K. K.R. and R.d.N. acted as the second reviewers to confirm reliability of study selection by inspecting all abstracts (50% each). J.K. contributed to the main writing up of the review findings, with additional input from authors K.R. and R.d.N. All authors critically reviewed the final version for publication. All authors read and approved the final manuscript.

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Supplemental material

Supplemental material is available for this article online. Please contact the author for any additional information.

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