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, 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) guidelines[2] and the protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO 2016 CRD42016050717). Twelve electronic databases were searched from inception to 30/05/2019 (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 (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 over) 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 pre-crossover 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, e.g., 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: 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 Appendix 4). One author developed and used a bespoke data extraction form, which was modelled on the Template for Intervention Description and Replication (TIDieR) checklist[4], 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].

Results

Six studies were included in the review. Figure 1 presents a PRISMA flow diagram. Reasons for exclusion are presented in 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 (Appendix 4). A total of 244 people with acquired brain injury were recruited and randomised across the studies. Five studies used a parallel group design[6-10] and one a crossover design[11] (Appendix 5). Only one study[7] 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.

All studies described their interventions sufficiently well to be compliant with the TIDieR checklist[12]. They used different types of personal smart technology (Appendix 6): planning system on a personal digital assistant[10], metronome smartphone application for stroke patients[7], paging device called Neuropage[11], standard mobile phone[8] text messages, and an iPad tablet[9] 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 study[10] (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 8 weeks compared to the control (mean difference 1.6, 95% CI 1.0 to 2.2, p=0.0001) (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 (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 study[10] (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 study[8] (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 8 weeks' post-intervention, the 'social relations' scores significantly improved in the intervention group compared to the control (p=0.01).

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 one[9] 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 interventions. 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 ABI. 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, one[6] 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[13]. 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[14, 15] meaning personalisation of interventions should be reported better in future studies to facilitate replication and improve intervention design. The TIDieR checklist[12] 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 checklist[16]) 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 ABI. 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)[17, 18] 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 interventions[19], and are increasingly being recommended as

the primary outcomes from funders such as the National Institute for Health Research. 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 sequalae of acquired brain injury, that are often more difficult to manage, such as fatigue and mood problems. Our findings resonate with findings from a 2015 review by Charters et al., which also identified a lack of studies evaluating the effect of technology on the greater needs of the acquired brain injury population[20]. 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, 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[21], which used the Rivermead Post-concussion Symptoms Questionnaire[21, 22]. 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, e.g., memory impairment, fatigue management, etc. 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, 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 view[23] 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 underreported.

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.

Acknowledgements

The authors would like to thank Jeanette Eldridge, senior research librarian at the University of Nottingham, for her help developing the search strategy for this review.

Author contributions

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

Competing interests

None declared.

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Supplementary materials

Included are the appendices discussed in this paper: (1) example search strategy, (2) exclusion of studies summary table, (3) PEDro scale of quality for included studies, (4) study methods and participant characteristics of included studies, (5) details of interventions used in the included studies, (6) primary outcome data from included studies, (7) secondary outcome data from included studies. Please contact the author for any additional information.

238 **Figure 1: PRISMA flow diagram of study selection process**

239

240

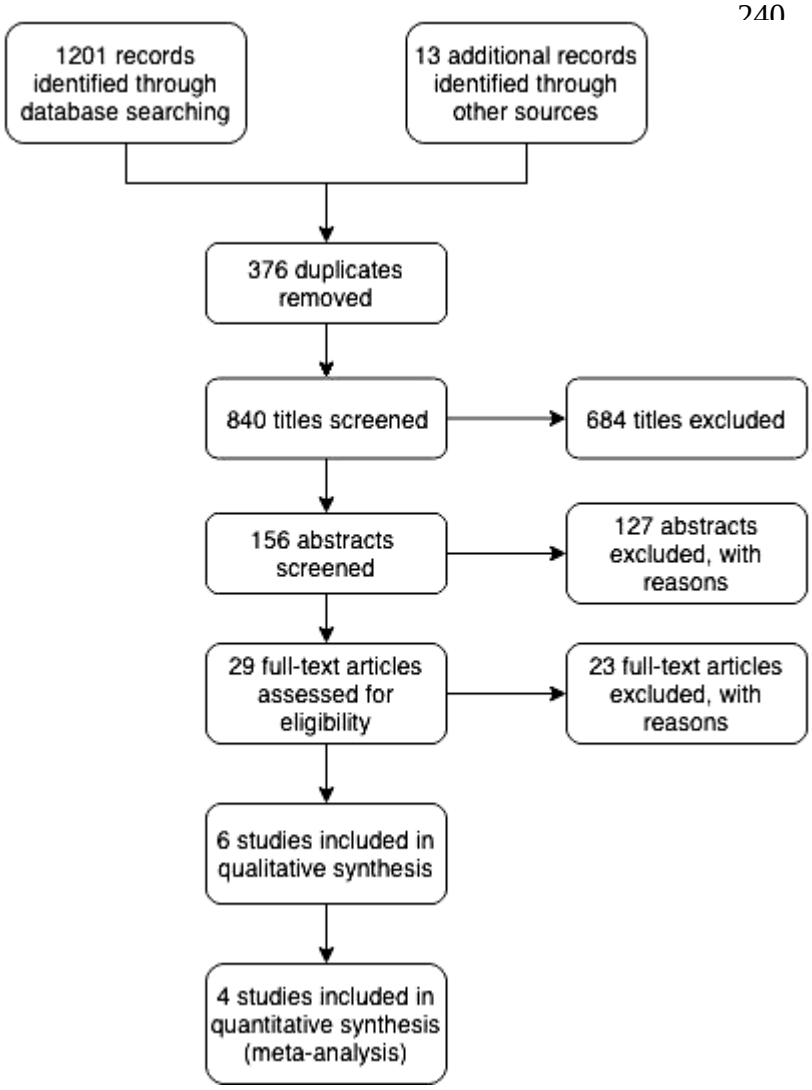
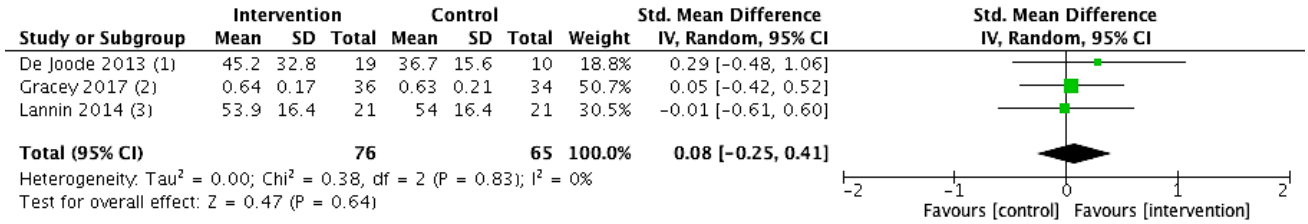
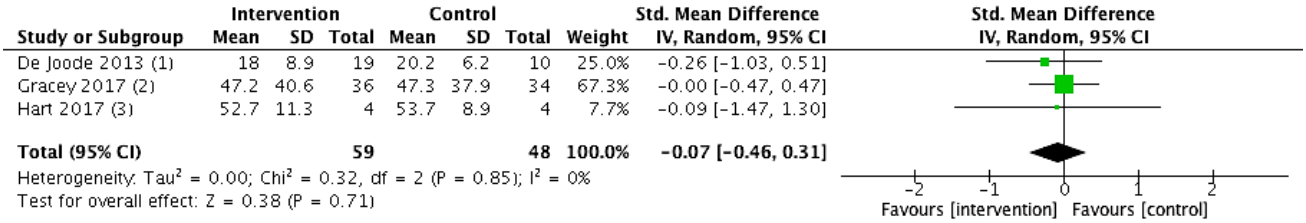


Figure 2: Meta-analysis of goal (or intention) attainment outcome measures for three studies. For each study, the box represents the random effects standardised mean difference and the line the 95% confidence intervals. The size of each box indicates the relative weight of each study in the meta-analysis.



Footnotes
(1) Goal attainment scale total (De Joode et al., 2013)
(2) Intention attainment (Gracey et al., 2017)
(3) Goal attainment scale total (Lannin et al., 2014)

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.



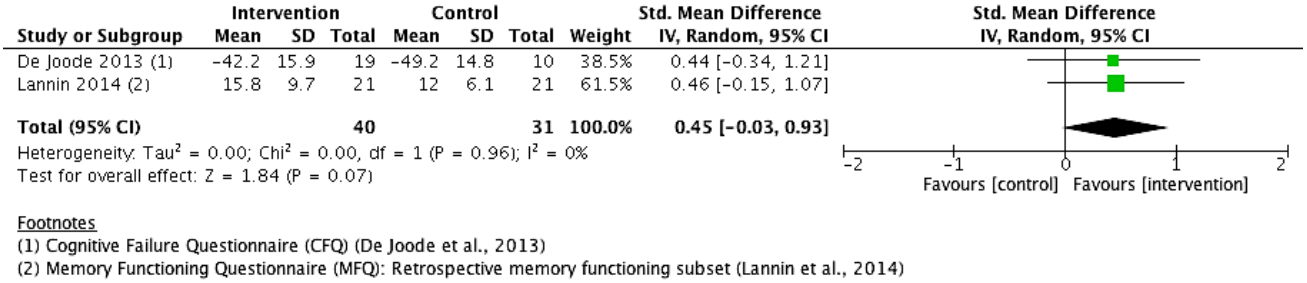
Footnotes

(1) Centre for Epidemiologic Studies Depression Scale; CES-D (De Joode et al., 2013)

(2) Profile of Mood states total mood disturbance; POMS-MD (Gracey et al., 2017)

(3) Brief Symptom Inventory Global Severity Index (BSI-GSI) (Hart et al., 2017)

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.



Footnotes
(1) Cognitive Failure Questionnaire (CFQ) (De Joode et al., 2013)
(2) Memory Functioning Questionnaire (MFQ): Retrospective memory functioning subset (Lannin et al., 2014)

Appendices

Appendix 1: Databases searched

Database	Dates searched
Cochrane Central Register of Controlled Trials (CENTRAL, The Cochrane Library)	Inception to May 2019
Ovid MEDLINE(R), Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid OLDMEDLINE(R)	Inception to May 2019
Embase Classic + Embase (OvidSP)	Inception to May 2019
CINAHL Plus	Inception to May 2019
PsycINFO (OvidSP)	Inception to May 2019
PubMed (limited to references not indexed in MEDLINE)	Inception to May 2019
HMIC (Ovid) Health Management Information Consortium	Inception to May 2019
AMED (Ovid) (Allied and Complementary Medicine)	Inception to May 2019
The Joanna Briggs Institute EBP Database	Inception to May 2019
EBSCO ERIC (Education Resource Information Centre)	Inception to May 2019
National Institute for Health Research (UK) (www.portal.nihr.ac.uk)	May 2019
UK Clinical Research Network (www.public.ukcrn.org.uk).	May 2019

Appendix 2: Example search strategy

1. randomi?ed controlled trial.pt.
2. controlled clinical trial.pt.
3. randomi?ed.ab.
4. placebo.ab.
5. randomly.ab.
6. trial.ab.
7. groups.ab.
8. or/1-7
9. Brain Injuries/
10. Brain Concussion/
11. Brain Hemorrhage, Traumatic/
12. Brain Injury, Chronic/
13. Diffuse Axonal Injury/
14. brain injur*.ti,ab.
15. (TBI or TBIs).ti,ab.
16. (hypoxic brain damage or diffuse axonal injur* or DAI or DAIs).ti,ab.
17. head injur*.ti,ab.
18. (brain adj2 trauma*).ti,ab.
19. (head adj2 trauma*).ti,ab.
20. concussion.ti,ab.
21. brain contusion.ti,ab.
22. cerebrovascular disorders/ or basal ganglia cerebrovascular disease/ or exp brain ischemia/ or carotid artery diseases/ or carotid artery thrombosis/ or intracranial arterial diseases/ or cerebral arterial diseases/ or exp intracranial embolism and thrombosis/ or exp stroke/
23. (isch?emi$ adj6 (stroke$ or apoplex$ or cerebral vasc$ or cerebrovasc$ or cva)).tw.
24. ((brain or cerebr$ or cerebell$ or vertebrobasil$ or hemispher$ or intracran$ or intracerebral or infratentorial or supratentorial or middle cerebr$ or mca$ or anterior circulation) adj5 (isch?emi$ or infarct$ or thrombo$ or emboli$ or occlus$ or hypoxi$)).tw.
25. or/9-24
26. exp Cellular Phone/
27. Computers, Handheld/
28. (handheld or hand-held) adj1 (computer? or pc?).mp.
29. cell$ phone?.mp.
30. mobile phone?.mp.
31. smartphone?.mp.
32. smart-phone?.mp.
33. (personal digital assistant? or PDA?).mp.
34. palmtop computer?.mp.
35. (tablet adj3 (device? or comput$)).mp.
36. Blackberry.mp.
37. Nokia.mp.
38. Symbian.mp.
39. (windows adj3 (mobile? Or phone?)).mp.
40. sidekick.mp.
41. Android.mp.

42. (phone adj3 call*).mp. OR ((cell* or mobile or smart or google or nexus or iphone) adj3 (phone* or telephone*)).mp. OR smart-phone*.mp. OR smartphone*.mp. OR (blackberr* not extract).mp. OR (black-berr* not extract).mp. OR (mobile adj3 health)
43. (mobile adj3 technol*).mp. OR ((mobile or smartphone or smart-phone or phone or software) adj3 app*).mp. OR MMS.mp. OR multimedia messaging service.mp. OR SMS.mp. OR short messag* service.mp. OR (text* adj messag*).mp. OR text-messa*.mp. OR voice messag*.mp. OR interactive voice response.mp. OR IVR.mp. OR Telemedicine/ OR cellular phone/ OR Text Messaging/
44. MP3-Player/
45. iphone$.tw.
46. ipad.tw.
47. ipod.tw.
48. (mhealth or m-health or m health).tw.
49. mobile health.tw.
50. Samsung.mp.
51. Or/26-50
52. exp rehabilitation/
53. (rehab* or (activit* adj2 daily living)).tw.
54. (re-abl* or reabl* or enablement or empower* or restor* or re-learn* or relearn*).tw.
55. recovery of function/
56. ((recover* or optim* or maintain* or increas* or improv* or independen* or ability or outcome*) adj3 function*).tw.
57. ((enabl* or recover* or maintain* or develop* or living) adj3 independen*).tw.
58. Occupational therapy/
59. exp “activities of daily living”/
60. exp rehabilitation, vocational/ or Rehabilitation/ or Self care/
61. exp leisure activities/
62. exp “recovery of function”/
63. exp work/ or Human activities/
64. Social adjustment/ or Social behavior/ or Social facilitation/
65. Social environment/ or Social support/
66. Goals/
67. occupational therap$.tw.
68. (activities of daily living or adl$ or eadl$).tw.
69. rehabilitation.tw.
70. ((self or personal) adj5 (care or manage $)).tw.
71. (dressing or feeding or eating or toilet$ or bathing or mobil$ or driving or public transport$).tw.
72. ((daily or domestic or house or home) adj5 (activit$ or task$ or skill$ or chore$)).tw.
73. leisure.tw.
74. (recover$ adj5 function$).tw.
75. (social adj5 (activit$ or function$ or support$ or skill$ or adjust$ or behavio?r or facilitat$)).tw.
76. (counsel?ing or goal$ or work or employment).tw.
77. or/52-76
78. 25 and 51 and 77
79. animals/not (humans/ and animals/)
80. 78 not 79
81. 80 and 8

Appendix 3: Exclusion of studies summary table

	Study Reference	Primary reason for Exclusion
1	Archer, K. R., Coronado, R. A., Haislip, L. R., Abraham, C. M., Vanston, S. W., Lazaro, A. E., . . . Obremskey, W. T. (2015). Telephone-based goal management training for adults with mild traumatic brain injury: study protocol for a randomized controlled trial. Trials [Electronic Resource], 16, 244.	Not original research with results - protocol
2	Akhand, O., Galetta, M. S., Cobbs, L., Hasanaj, L., Webb, N., Drattell, J., . . . Balcer, L. J. (2018). The new Mobile Universal Lexicon Evaluation System (MULES): A test of rapid picture naming for concussion sized for the sidelines. *Journal of the Neurological Sciences, 387*, 199-204.	Not adults with ABI
3	Audebert, H. J., Boy, S., Jankovits, R., Pilz, P., Klucken, J., Fehm, N. P., & Schenkel, J. (2008). Is mobile teleconsulting equivalent to hospital-based telestroke services? Stroke, 39(12), 3427-3430.	Not RCT
4	Audebert, H. J., Wimmer, M. L. J., Schenkel, J., Ulm, K., Kolominsky-Rabas, P. L., Bogdahn, U., . . . Haberl, R. L. (2004). [Telemedicine stroke department network. Introduction of a telemedicine pilot project for integrated stroke management in South Bavaria and analysis of its efficiency]. Nervenarzt, 75(2), 161-165.	Not RCT
5	Baker, V. B., Eliasen, K. M., & Hack, N. K. (2018). Lifestyle modifications as therapy for medication refractory post-traumatic headache (PTHA) in the military population of Okinawa. *Journal of Headache and Pain, 19*(1), 113.	Not RCT
6	Baldwin, V. N., & Powell, T. (2015). Google Calendar: A single case experimental design study of a man with severe memory problems. Neuropsychol Rehabil, 25(4), 617-636.	Not RCT
7	Barrows, P. D., & Thomas, S. A. (2018). Assessment of mood in aphasia following stroke: validation of the Dynamic Visual Analogue Mood Scales (D-VAMS). *Clinical rehabilitation, 32*(1), 94-102.	Not RCT
8	Bedell, G. M., Wade, S. L., Turkstra, L. S., Haarbauer-Krupa, J., & King, J. A. (2016). Informing design of an app-based coaching intervention to promote social participation of teenagers with traumatic brain injury. *Dev Neurorehabil*, 1-10. doi:10.1080/17518423.2016.1237584	Not adults with ABI
9	Bell, K., Brockway, J., Hart, T., Whyte, J., Sherer, M., & Fraser, R. (2011). Scheduled telephone intervention for traumatic brain injury: A multicenter randomized controlled trial. Arch Phys Med Rehabil, 92(10), 1552-1560.	Not personal smart technology
10	Bell, K. R., Brockway, J. A., Fann, J. R., Cole, W. R., De Lore, J. S., Bush, N., . . . Temkin, N. (2015). Concussion treatment after combat trauma: Development of a telephone based, problem solving intervention for service members. Contemporary Clinical Trials 40 (pp 54-62), 2015, Date of Publication, January 01.	Not original research with results - protocol
11	Bell, K. R., Fann, J., Brockway, J. A., Cole, W. R., Bush, N., Dikmen, S., . . . Temkin, N. (2015). Telephone problem solving treatment for active duty service members with mild traumatic brain injury. PM and R, Conference, 2015 Annual Assembly of the American Academy of Physical Medicine and Rehabilitation Boston, MA United States.	Not personal smart technology
12	Benvenuti, F., Stuart, M., Cappena, V., Gabella, S., Corsi, S., Taviani, A., . . . Weinrich, M. (2014). Community-based exercise for upper limb paresis: a controlled trial with telerehabilitation. Neurorehabilitation & Neural Repair, 28(7), 611-620.	Not RCT
13	Bishop, D., Miller, I., Weiner, D., Guilmette, T., Mukand, J., Feldmann, E., . . . Springate, B. (2014). Family Intervention: Telephone Tracking (FITT): A pilot stroke outcome study. Topics in Stroke Rehabilitation Vol, 21(Supp1), S63-S74.	Not personal smart technology
14	Boman, I., Bartfai, A., Borell, L., Tham, K., & Hemmingsson, H. (2010). Support in everyday activities with a home-based electronic memory aid for persons with memory impairments. Disability & Rehabilitation: Assistive Technology, 5(5), 339-350 312p.	Not RCT
15	Bombardier, C. H., Bell, K. R., Temkin, N. R., Fann, J. R., Hoffman, J., & Dikmen, S. (2009). The efficacy of a scheduled telephone intervention for ameliorating depressive symptoms during the first year after traumatic brain injury. Journal of Head Trauma Rehabilitation, 24(4), 230-238 239p.	Not personal smart technology
16	Bourgeois, M. S., Lenius, K., Turkstra, L., & Camp, C. (2007). The effects of cognitive teletherapy on reported everyday memory behaviours of persons with chronic traumatic brain injury. Brain Injury Vol, 21(12), 1245-1257.	Not personal smart technology
17	Brown, R., Pain, K., Berwald, C., Hirschi, P., Delehanty, R., & Miller, H. (1999). Distance education and caregiver support groups: comparison of traditional and telephone groups. Journal of Head Trauma Rehabilitation, 14(3), 257-268.	Not adults with ABI
18	Cadilhac, D., Andrew, N., Busingye, D., Cameron, J., Thrift, A., Kneebone, I., . . . Kilkenny, M. (2018). Pilot randomised controlled trial of an e-health discharge support intervention for stroke. *International Journal of Stroke, 13*(2 Supplement 1), 49-50.	Could not retrieve full text – abstract only
19	Chang, Y.-J., Chen, S.-F., & Chou, L.-D. (2012). A Feasibility Study of Enhancing Independent Task Performance for People with Cognitive Impairments Through the Use of a Handheld Location-Based Prompting System. IEEE Transactions on Information Technology in Biomedicine, 16(6), 1157-1163.	Not RCT
20	Charters, E., Gillett, L., & Simpson, G. K. (2015). Efficacy of electronic portable assistive devices for people with acquired brain injury: a systematic review. *Neuropsychol Rehabil, 25*(1), 82-121.	Not original research with results – systematic review
21	Chen, C., Huang, X., Yang, Y., Liu, X., Yang, C., Song, Q., . . . Zhou, H. (2018). Media access and anaemia prevalence in children from ethnic minorities aged 6-23 months in central and western China: a cross-sectional study. *The Lancet, 392*(Supplement 1), S69.	Not adults with ABI
22	Cho, J. E., Cho, K. H., Yoo, J. S., Lee, S. J., & Lee, W. H. (2018). Reliability and validity of a dual-probe personal computer-based muscle viewer for measuring the pennation angle of the medial gastrocnemius muscle in patients who have had a stroke. *Topics in Stroke Rehabilitation, 25*(1), 6-12.	Not RCT
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112	Rietdijk, R., Togher, L., & Power, E. (2012). Supporting family members of people with traumatic brain injury using telehealth: A systematic review. J Rehabil Med, 44(11), 913-921.	Not original research with results – systematic review
113	Rochette, A., Korner-Bitensky, N., Bishop, D., Teasell, R., White, C., Bravo, G., . . . Wood-Dauphinee, S. (2013). Best practices when facing daily challenges after a first mild stroke: You call or we call? Stroke, Conference, 2013 Canadian Stroke Congress Montreal, QC Canada. Conference Start: 20131017 Conference End: 20131019. Conference Publication: (var.pagings). 20131044 (20131012) (pp e20131221-e20131222).	Not personal smart technology
114	Rochette, A., Korner-Bitensky, N., Bishop, D., Teasell, R., White, C., Bravo, G., . . . Wood-Dauphinee, S. (2010). Study protocol of the YOU CALL--WE CALL TRIAL: impact of a multimodal support intervention after a "mild" stroke. BMC Neurol, 10, 3.	Not original research with results - protocol
115	Roots, A., Bhalla, A., & Birns, J. (2011). Telemedicine for stroke: A systematic review. British Journal of Neuroscience Nursing, 7(2), 481-489.	Not RCT
116	Rous, R., Adams, M., Fish, J., Manly, T., & Adlam, A. (2012). Prospective memory intervention for adolescents with acquired brain injury: Developmental and psychosocial factors affecting outcomes. Brain Impairment, Conference, 9th Annual Conference of the Special Interest Group in Neuropsychological Rehabilitation of the World Federation for NeuroRehabilitation, WFNR 2012 Bergen Norway.	Not adults with ABI
117	Rubin, M. N., Wellik, K. E., Channer, D. D., & Demaerschalk, B. M. (2013). Role of telemedicine in providing tertiary neurological care. Curr Treat Options Neurol, 15(5), 567-582.	Not original research with results - opinion piece
118	Salaris, M., de Vries, R., Jordan, L. A., Quinn, R., Young, A. D., Paisley, E., & Janssen, H. (2014). How frequently and for what purpose is tablet technology being used during stroke recovery? *International Journal of Stroke, Conference*, 10th Australasian Nursing and Allied Health Stroke Conference, Smart Strokes 2014 Sydney , NSW Australia. Conference Start: 20140828 Conference End: 20140829. Conference Publication: (var.pagings). 20140829 (pp 20140827-20140828).	Not original research with results – protocol abstract

119	Saposnik, G., Chow, C.-M., Gladstone, D., Cheung, D., Brawer, E., Thorpe, K. E., . . . i, H. R. T. f. t. S. O. R. C. W. G. (2014). iPad technology for home rehabilitation after stroke (iHOME): a proof-of-concept randomized trial. International Journal of Stroke, 9(7), 956-962.	Not RCT
120	Sarfo, F., Treiber, F., Gebregziabher, M., Adamu, S., Patel, S., Nichols, M., . . . Ovbiagele, B. (2018). PINGS (Phone-Based Intervention Under Nurse Guidance After Stroke): Interim Results of a Pilot Randomized Controlled Trial. *Stroke, 49*(1), 236-239.	No measure of primary outcomes
121	Sarfo, F. S., & Ovbiagele, B. (2017). Response by Sarfo and Ovbiagele to letter regarding "potential role of tele-rehabilitation to address barriers to implementation of physical therapy among West African stroke survivors: A cross-sectional survey". *Journal of the Neurological Sciences, 382*, 162-163.	Not RCT
122	Sarfo, F. S., Treiber, F., Jenkins, C., Patel, S., Gebregziabher, M., Singh, A., . . . Ovbiagele, B. (2016). Phone-based Intervention under Nurse Guidance after Stroke (PINGS): study protocol for a randomized controlled trial. *Trials, 17*(1), 436.	Not original research with results – protocol
123	Savulich, G., Thorp, E., Piercy, T., Peterson, K. A., Pickard, J. D., & Sahakian, B. J. (2019). Improvements in attention following cognitive training with the novel "decoder" game on an ipad. *Frontiers in Behavioral Neuroscience, 13*, 2.	Not adults with ABI
124	Saywell, N., Vandal, A. C., Brown, P., Hanger, H. C., Hale, L., Mudge, S., . . . Taylor, D. (2012). Telerehabilitation to improve outcomes for people with stroke: study protocol for a randomised controlled trial. Trials [Electronic Resource], 13, 233.	Not original research with results - protocol
125	Schliessmann, D., Nisser, M., Schuld, C., Gladow, T., Derlien, S., Heutehaus, L., . . . Rupp, R. (2018). Trainer in a pocket - Proof-of-concept of mobile, real-time, foot kinematics feedback for gait pattern normalization in individuals after stroke, incomplete spinal cord injury and elderly patients. *Journal of NeuroEngineering and Rehabilitation, 15*(1), 44.	Not RCT
126	Schoenberg, M. R., Ruwe, W. D., Dawson, K., McDonald, N. B., Houston, B., & Forducey, P. G. (2008). Comparison of functional outcomes and treatment cost between a computer-based cognitive rehabilitation teletherapy program and a face-to-face rehabilitation program. Professional Psychology: Research and Practice Vol, 39(2), 169-175.	Not personal smart technology
127	Scrivener, K., Dean, C., Stevens, G., & Chan, V. (2018). Home-based, tailored exercise and safety intervention for reducing falls after stroke is acceptable, safe and feasible. *International Journal of Stroke, 13*(1 Supplement 1), 34.	Not RCT
128	Seixas, D. (2018). Impact of a mobile app on the efficiency of clinical communication: Coordination of care in acute stroke. *Neuroradiology, 60*(8), 882.	Not adults with ABI
129	Silveira, T., Tamplin, J., & Dorsch, S. (2018). Investigating the effect of Functional Electrical Stimulation+iPad-based music therapy on arm recovery after stroke: Protocol for a Randomised Control Trial. *International Journal of Stroke, 13*(1 Supplement 1), 39.	Not original research with results - protocol
130	Singer, J., Weingast, S., Stefanov, D., Gilles, N., Girouard, S., Faysel, M., . . . Levine, S. (2017). Developing a mobile application for stroke caregivers. *Neurology, 88*(16 Supplement 1).	Not adults with ABI
131	Sloane, K. L., Wright, A., Saxena, S., & Hillis, A. E. (2018). Supervised, self administered tablet based cognitive assessment in neurodegenerative disorders. *Stroke, 49*(Supplement 1).	Not personal smart technology
132	Smith, G. C., Egbert, N., Dellman-Jenkins, M., Nanna, K., & Palmieri, P. A. (2012). Reducing depression in stroke survivors and their informal caregivers: a randomized clinical trial of a Web-based intervention. Rehabilitation Psychology, 57(3), 196-206.	Not personal smart technology
133	Stapleton, S., Adams, M., & Atterton, L. (2007). A mobile phone as a memory aid for individuals with traumatic brain injury: A preliminary investigation. . Brain Inj, 21(4), 401-411.	Not RCT
134	Suffoletto, B., Wagner, A. K., Arenth, P. M., Calabria, J., Kingsley, E., Kristan, J., & Callaway, C. W. (2013). Mobile phone text messaging to assess symptoms after mild traumatic brain injury and provide self-care support: a pilot study. *Journal of Head Trauma Rehabilitation, 28*(4), 302-312.	No measure of primary outcomes
135	Sureshkumar, K., Murthy, G. V. S., & Kuper, H. (2018). Protocol for a randomised controlled trial to evaluate the effectiveness of the Care for Stroke' intervention in India: A smartphone-enabled, carer-supported, educational intervention for management of disabilities following stroke. *BMJ Open, 8*(5), 020098.	Not original research with results - protocol
136	Sureshkumar, K., Murthy, G. V., Munuswamy, S., Goenka, S., & Kuper, H. (2015). 'Care for Stroke', a web-based, smartphone-enabled educational intervention for management of physical disabilities following stroke: feasibility in the Indian context. BMJ Innov, 1(3), 127-136. doi:10.1136/bmjinnov-2015-000056	Not RCT
137	Sweetapple, A., & Gilbert, J. (2014). Photography and technology: The introduction and sharing of a new leisure activity for stroke survivors. International Journal of Stroke, Conference, 10th Australasian Nursing and Allied Health Stroke Conference, Smart Strokes 2014 Sydney, NSW Australia. Conference Start: 20140828 Conference End: 20140829. Conference Publication: (var.pagings). 20140829 (pp 20140830).	Not RCT
138	Szymkowiak, A., Morrison, K., Gregor, P., Inglis, E. A., Shah, P., Evans, J. J., & Wilson, B. A. (2005). A memory aid with remote communication: Preliminary findings. Technology and Disability, 17(4), 217-225.	Not RCT
139	Taylor, D., Saywell, N., Mudge, S., Hale, L., Brown, P., Feigin, V., . . . Vandal, A. (2018). Telerehabilitation can improve outcomes after stroke; but only if you do it. *International Journal of Stroke, 13*(2 Supplement 1), 235	Not personal smart technology
140	Taylor, D. M., Stone, S. D., & Huijbregts, M. P. (2012). Remote participants' experiences with a group-based stroke self-management program using videoconference technology. Rural & Remote Health, 12, 1947.	Not RCT
141	Tornas, S., Lovstad, M., Solbakk, A.-K., Evans, J., Endestad, T., Hol, P. K., . . . Stubberud, J. (2016). Rehabilitation of Executive Functions in Patients with Chronic Acquired Brain Injury with Goal Management Training, External Cuing, and Emotional Regulation: A Randomized Controlled Trial. *Journal of the International Neuropsychological Society, 22*(4), 436-452.	No measure of primary outcomes
142	Vahlberg, B., Holmback, U., Eriksson, S., & Cederholm, T. (2018). Protocol and pilot study of a short message service-guided training after acute stroke/transient ischemic attack to increase walking capacity and physical activity. *Preventive medicine reports, 11*, 109-114.	Not original research with results - protocol
143	van Hoof, J., Kort, H., Rutten, P., & Duijnstee, M. (2010). Ageing-in-place by use of smart home technology...Fourth European Nursing Congress. Journal of Clinical Nursing, 19, 101-101 101p. doi:10.1111/j.1365-2702.2010.03444.x	Not adults with ABI
144	van Til, J., Drossaert, C., Renzenbrink, G., Snoek, G., Dijkstra, E., Stiggelbout, A., & Ijzerman, M. (2010). Feasibility of web-based decision aids in neurological patients. J Telemed Telecare, 16(1), 48-52.	Not RCT
145	Vloothuis, J., Mulder, M., Nijland, R. H., Konijnenbelt, M., Mulder, H., Hertogh, C. M., . . . van Wegen, E. (2015). Caregiver-mediated exercises with e-health support for early supported discharge after stroke (CARE4STROKE): Study protocol for a randomized controlled trial. BMC Neurology Vol, 15(1), 193.	Not original research with results - protocol
146	Wade, S. L., Bedell, G., King, J. A., Jacquin, M., Turkstra, L. S., Haarbauer-Krupa, J., . . . Narad, M. E. (2018). Social Participation and Navigation (SPAN) program for adolescents with acquired brain injury: Pilot findings. *Rehabilitation psychology, 63*(3), 327-337.	Not adults with ABI
147	White, C. L., Ihegword, B., Patterson, M., Motz, D., Williamson, R., Caron, J. L., & Birnbaum, L. A. (2016). Feasibility testing of mhealth for brainhealth: A mobile intervention to support secondary stroke prevention. *Stroke, 47*.	Not RCT
148	Wild, M., & Schwartz, S. H. (2008). Memory compensation using the pocket PC: Making cognitive connections for brain injury survivors. Journal of Head Trauma Rehabilitation, Conference, North American Brain Injury Society's 6th Annual Conference on Brain Injury New Orleans, LA United States. Conference Start: 20081002 Conference End: 20081004. Conference Publication: (var.pagings). 20081023 (20081005) (pp 20081352-20081353).	Not RCT
149	Wilson, B. (2010). Rehabilitation of memory disorders. Journal of Neurology, Neurosurgery and Psychiatry, Conference, Section of Neuropsychiatry of RCPsych and British Neuropsychiatry Association Joint Conference London United Kingdom. Conference Start: 20100210 Conference End: 20100212. Conference Publication: (var.pagings). 20100281 (2010	Not RCT
150	Woodhead, Z. V. J., Kerry, S. J., Aguilar, O. M., Ong, Y.-H., Hogan, J. S., Pappa, K., . . . Crinion, J. T. (2018). Randomized trial of iReadMore word reading training and brain stimulation in central alexia. *Brain, 141*(7), 2127-2141. doi:10.1093/brain/awy138	No measure of primary outcomes

Appendix 4: PEDro scale of quality for included studies

	PEDro Item Number											
Study ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
De Joode, 2013[6]	I	I	I	I	0	0	0	I	I	I	I	8
Gracey, 2017[11]	I	I	I	I	0	0	I	0	I	I	I	8
Kim, 2012[7]	I	I	0	I	0	0	0	I	0	I	I	6
Lannin, 2014[10]	I	I	I	I	0	0	I	I	I	I	I	9
Hart, 2017[8]	I	I	0	I	0	0	I	I	I	I	I	8
Emmerson, 2017[9]	I	I	I	I	0	0	I	I	0	I	I	7

I = satisfied item criterion, 0 = did not satisfy item criterion

Item 1: Eligibility criteria were specified; *Item 2*: Subjects were randomly allocated; *Item 3*: Allocation was concealed; *Item 4*: Groups were similar at baseline regarding the most important prognostic indicators; *Item 5*: There was blinding of all subjects; *Item 6*: There was blinding of all therapists who administered the therapy; *Item 7*: There was blinding of all assessors who measured at least one key outcome; *Item 8*: Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; *Item 9*: All subjects for whom outcome measures were available received the treatment or control condition as allocated or data for at least one key outcome was analysed by “intention to treat”; *Item 10*: The results of between-group statistical comparisons are reported for at least one key outcome; *Item 11*: The study provides both point measures and measures of variability for at least one key outcome.

Appendix 5: Study methods and participant characteristics of included studies

ABI: acquired brain injury; PDA: personal digital assistant; RCT: randomised controlled trial; TBI: traumatic brain injury

Study ID	De Joode, 2013[6]	Gracey, 2017[11]	Kim, 2012[7]	Lannin, 2014[10]	Hart, 2017[8]	Emmerson, 2017[9]
Aim	Aim of the study was to compare the effects of the PDA with paper based methods in terms of everyday activities after acquired brain injury.	Aim of study to examine the efficacy of Assisted Intention Monitoring (brief goal management training) followed by SMS text messages sent randomly to the participant's phone.	Aim of the study was to examine the effects of gait training using a metronome smartphone application on balance and gait abilities in stroke patients.	Aim of the study was to determine if a PDA was more effective than non-electronic memory aids after acquired brain injury.	Aim of study was to explore if people with traumatic brain injury could create implementation intentions (self-regulatory strategy which aims to promote goal attainment) in line with specific goals and reply to SMS text reminders.	Aim of study was to compare adherence to upper limb home exercise programs provided using video/reminders on touch-screen tablets compared with home exercises provided using a paper-based method for people with stroke.
Design/ Allocation	RCT, parallel group design.	RCT, parallel group, crossover design. Blocked sequence randomisation.	RCT, '*Randomly and equally divided into intervention group and control group'*	RCT, '*Computer generated randomised allocation schedule'.*	RCT, randomisation was stratified.	RCT, blocked sequence randomisation. Allocation concealed.
Blinding	No blinding as it was not possible due to nature of the intervention.	Assessments and primary analyses were conducted blind to group allocation.	No blinding.	Patients and caregivers were aware of allocation, but assessors were blind to group allocation.	Assessors were blind to group allocation.	Assessors were blind to group allocation.
Duration	16 hours training, follow-up 4-6 months after training.	9 weeks, 3 weeks in each phase.	5 weeks.	8 weeks.	8 weeks.	4 weeks.
Setting	7 rehabilitation centres Netherlands and patient homes.	UK community services in East Anglia region.	Stroke inpatient ward at 'S' Rehabilitation Hospital in Seoul, South Korea.	Brain injury rehab unit, community rehab service, and private occupational therapy practice. Australia.	Outpatient brain injury community re-entry programme, patient homes in Pennsylvania, USA.	Community rehabilitation programme sites in Melbourne, Australia.
Participant numbers & demo-graphics	**Diagnosis:** ABI **n =** 40 randomised **Age**: Intervention group mean= 42.2 years; Control group mean= 39.4 years **Gender**: Intervention group = 14 men, 7 women; Control group = 10 men, 3 women **Aetiology**: - Stroke n=12 (intervention n=7, control n=5) - TBI n=11 (intervention n=6, control n=5) - Brain tumour n=3 (intervention n=1, control n=2) - Mixed stroke/TBI n=3 (intervention n=2, control n=1) - Other n=5 (intervention n=5, control n=0) **Mean time post-injury:** - Intervention group = 38.9 months - Control group = 65.9 months	**Diagnosis:** ABI **n =** 74 randomised, 36 in first intervention phase **Age:** Intervention first mean= 46.36 years; Control first mean= 50.18 years **Gender:** Intervention first (intention to treat) = 23 men, 13 women Control first = 23 men, 11 women. **Aetiology**: - CVA n=23 (intervention first n=11, control first n=12) - Infection n=3 (intervention first n=2, control first n=1) - TBI n=33 (intervention first n=17, control first n=16) - Tumour n=10 (intervention first n=6, control first n=4) **Mean time post-injury:** - Intervention first (intention to treat) = 4.89 years - Control first = 8.62 years	**Diagnosis:** Stroke **n =** 20 randomised **Age:** Intervention group mean= 58.3 years; Control group mean= 51.8 **Gender:** Intervention group = 6 men, 4 women. Control group = 7 men, 3 women **Aetiology:** - Infarction n=8 (intervention n=6, control n=2) - Haemorrhage n=12 (intervention n=4, control n=8) **Side of hemiplegia:** - Right side n= 8 (intervention n=5, control n=3) - Left side n=12 (intervention n=5, control n=7)	**Diagnosis:** ABI **n =** 42 **Age:** Intervention group mean= 34 years 8 months; Control group mean= 32 years 5 months **Gender:** Intervention group = 12 men, 9 women Control group = 14 men, 7 women **Aetiology:** - Closed TBI n = 31 - Open TBI n=0 - Initially closed with neurosurgery n=2 - Other n=6 **Mean time post-injury:** - Intervention group = 2363.9 days - Control group = 4379.8 days,	**Diagnosis:** TBI **n =** 8 randomised **Age:** Intervention group mean= 23.8 years, Control group mean = 34.3 **Gender:** Intervention group = 2 men, 2 women. Control group = 3 men, 1 woman **Cause of TBI:** - Motor vehicle n=6 (intervention n=3, control n=3) - Fall n=1 (intervention n=1, control n=0) - Assault n=1 (intervention n=0, control n=1) **Median time post-TBI:** - Intervention group = 2.5 years (0.75-7.0) - Control group = 2.7 years (1.3-4.0)	**Diagnosis:** Stroke **n =** 62 randomised **Age:** Intervention group mean = 68 years; Control group mean = 63 **Gender:** Intervention group = 17 men, 13 women. Control group = 19 men, 13 woman **Type of stroke:** - Infarct n=53 (intervention n=22, control n=27) - Haemorrhage n=9 (intervention n=6, control n=3) **Median time post-stroke:** - Intervention group = 122 days - Control group = 133 days
Inclusion criteria	1. Diagnosis of ABI. 2. Aged between 18-75. 3. Comprehension of Dutch. 4. Experiencing problems in daily life functioning. 5. Clinical judgement that use of external cognitive aids may be beneficial to the participant.	1. Diagnosis of non-progressive brain injury. 2. Aged 18 or over. 3. More than one year post-injury. 4. Clinician, carer or self-reported everyday organisation and memory problems. 5. Ability to use mobile phone.	1. Diagnosis of stroke with subacute hemiplegia. 2. No more than 6 months post-diagnosis. 3. No cognitive impairment (MMSE less than 24). 4. No visual, auditory, or orthopaedic injuries that may influence balance.	1. Diagnosis of ABI. 2. Aged 17 years or over. 3. Functional memory impairment (assessed by RBMT). 4. Emerged from post-traumatic amnesia. 5. Sufficient hand function to use a PDA.	1. Diagnosis of moderate to severe TBI. 2. At least 6 months post-injury. 3. Fluent in English. 4. Confirmation from the participant that at least one of the study goal areas were relevant for him/her following discharge.	1. Diagnosis of stroke. 2. Any degree of upper limb impairment. 3. Referred for occupational therapy.
Exclusion criteria	1. Visual or manual difficulties incompatible with normal PDA use 2. Severe psychiatric comorbidity 3. Progressive neurological disorder	1. Memory impairment of sufficient severity to limit retention of intentions and training information.	Not reported.	1. No memory impairment. 2. Severe physical disability. 3. Living outside metropolitan Sydney. 4. Not English speaking.	1. History of serious mental illness. 2. Current serious psychiatric issues. 3. Significant cognitive disability not as a result of TBI.	1. Visual or cognitive deficits that would prevent use of the technology. 2. No carer or family member available to provide daily assistance (where necessary).

		2. Patient or carer participant with severe and enduring mental health problem. 3. Substance misuse/dependency. 4. Rehabilitation intervention with significant overlap with study intervention.			4. Enrolment in another intensive treatment programme. 5. No method for receiving voice, email or text messages.	
Control group	• Care-as-usual, aimed at learning skills and strategies to support memory, planning and organisation. • Most centres provided paper based training (e.g. paper diaries). • Received a fixed number of 16 hours of training.	• One-to-one sessions of the same duration as AIM consisting of brain injury information presented using Powerpoint. • Computerised visuospatial game involving increasingly speeded mental rotation ('Tetris'). • Received eight daily SMS text messages reading: 'AIM research study. Please ignore'.	• Thirty minutes of conventional therapy, ten times per week for a period of five weeks. • Conventional therapy was defined as 'one-on-one neurodevelopmental therapy between a patient and a therapist.	• Eight weeks use of a non-electronic memory aid. • Received individual and group sessions which focused on the use of non-electronic memory strategies to support daily living. • Included paper diaries, formation of lists and cueing strategies, integration of mneumonics.	• Received the Goal Review (GR) intervention. • Attended a session that included a brief didactic presentation on the importance of goals, discussion of goals they participant had achieved and goals they still wished to achieve.	• Given instructions for their home exercise programme in a written format, often including diagrams. • Participants who owned or had easy access to a touch-screen tablet were asked not to use video or reminder functions on their device as part of therapy programmes.
Drop outs	**Intervention group:** • Post treatment; no response n=1, unrelated death n=1, questionnaires not received n=2 • Follow-up; burden too high n=1, unrelated death n=1, questionnaires not returned n=9. **Control group:** • Post treatment; burden too high n=1, dissatisfied with allocation n=1, no response n=2, questionnaires not received n=3 • Follow-up; questionnaires not returned n=4.	**Withdrew following baseline assessments and prior to randomisation n=9** Too demanding n=5, memory impaired n=2, phone problems n=1, reason not known n=1 **Intervention first group:** withdrew following allocation n=1, did not complete intervention phase n=6, n=37 randomised to the intervention first group and n=29 completed. **Control first group:** withdrew following allocation n=3, did not complete control phase n=2, n=37 randomised to the control first group and n=30 completed.	**Dropouts n =1** - Participant left hospital halfway through the study	**Dropouts n=0** 100% adherence to study protocol.	**Dropouts n=4** • Withdrew following consent n=1, lost to contact • Withdrew following baseline assessments and prior to randomisation n=1 • Withdrew following introduction of intervention n=2 through agreement, unable to articulate a goal specific enough to create GAS.	**Dropouts n=4** • Died from unrelated medical issues (n=1) • Good progress and self-discharged from the community rehabilitation programme (n=3) -

Appendix 6: Details of personal smart technology interventions used in the included studies PDA: personal digital assistant

Study ID	De Joode, 2013[6]	Gracey, 2017[11]	Kim, 2012[7]	Lannin, 2014[10]	Hart, 2017[8]	Emmerson, 2017[9]
Brief description of personal smart technology	PEAT (Planning and Execution Assistant and Trainer) software provided on a PDA (Hewlett-Packard iPAQ HP114, Windows Mobile 6 operating system).	Assisted Intention Monitoring (AIM) which comprised brief goal management training followed by randomly-timed SMS text messages received on Neuropage device.	Rhythmic auditory stimulation (RAS) using metronome app on a smartphone.	PDA.	Implementation intentions created by participants, delivered as SMS text message reminders received on mobile phone.	Home exercise videos and reminders on a touch screen tablet.
Components of intervention	• PEAT was installed on PDA and took control of the device. • PEAT provides reminder function, 'floating task' function to allow automatic planning of specific tasks, and reschedule task if another interferes. • Has a 'wait button' which allows users to postpone the beginning or ending of a task. • Comprises four main modules: cue card, diary, notes section and names section. • Users reminded of start and end of task.	• Main parts of the program presented to participants on Powerpoint slides. • Slides covered the following: 1) utility of setting goals and breaking goals down into steps, 2) absent-mindedness and 'slip-ups', 3) using the 'mental blackboard' to take note of goals and steps, 4) checking status of one's intentions, which was linked to the acronym 'STOP' - Stop, Think, Organise, Plan. • Participants were sent 8 'STOP' texts each day, which was provided via a reminding service call Neuropage, which has the capacity to send SMS messages.	• Metronome application for a smartphone called ZyMi Metronome FREE for Android operating systems and was free of charge. • The metronome beat was provided as auditory stimulation through individual earphones.	• Lowest cost PDA available at the time that had the following features; alarm, calendar, address book and camera, but did not have telephone functionality. • A Windows platform PDA (Palm Z22, HP Palm, HPiPAQ) and a Macintosh platform PDA (MessagePad, ITouch) were available for selection .	• Implementation intentions were developed for each participant to promote goal attainment. • Specific SMS messages containing these implementation intentions were sent to the participants' phones at various times throughout the week and the individuals were required to respond with a phrase.	• During the first therapy session, a home exercise programme was developed by an OT with the participant, in line with usual practice. • An iPad was used to video the participant performing their home exercise programme with a commentary. • A reminder/alarm was set up to provide both a visual and audio daily exercise cue. • Videos updated throughout the programme upon review.
Who provided (and/or set up device)	PEAT training provided by therapists at various rehabilitation centres according to the centre's usual procedure.	Intervention delivered by a member of the research team, '*a qualified occupational therapist with significant experience in providing cognitive rehabilitation interventions both in clinical and research settings with people with stroke and ABI*'.	Not mentioned.	Occupational therapist (OT) provided support in the use of the PDA. All training modules were delivered by an experienced neurological OT.	Therapist(s) worked with each participant in the intervention group to develop implementation intentions that were relevant to their specific goals specified in the GAS.	The home exercise programme was developed by an OT with the participant. The OT provided the commentary for the iPad videos and they also updated the videos when the participant had a review.
Procedures and how it was delivered	• Following baseline, participants were encouraged to use the intervention as much as possible at home or rehabilitation centre, and integrate into daily routines. • Training (using predefined protocol) to use the device was provided for all intervention group participants. • Remainder of the training period was tailored to participants' specific needs. • Following training, participants completed post-treatment measures and given the opportunity to purchase the intervention at a reduced price.	• Brief GMT provided one-to-one in participants' homes or in community setting, over 2 sessions which were no more than 5 days apart. • Training materials were selected from the full GMT program and presented as a PowerPoint presentation with accompanying workbook. • Slides were supported with discussion of examples provided by the participant or in the workbook. • Participants told they would receive 8 texts each day stating the acronym 'STOP'. These would occur at random times between 8am and 6pm	• Rhythmic auditory stimulation training sessions were conducted in a rectangular gait training space, 20mx5m. • Training program consisted of 5 stages, each lasting 5 minutes, with a 1 minute break between each stage. • Participants were instructed to walk a 20m course repeatedly for 1 minute of training so they could adapt to the metronome beat. • Stages increased in complexity in time with the metronome beat. • Final stage: forward walking was performed by increasing cadence of a comfortable	• Participants chose and prioritised meaningful activities that they wanted to improve their independence in or memory. • There were 5 structured training modules provided over study period. • Key features of training modules included: selection of appropriate PDA, awareness of deficit training, training in basic PDA application skills, and use of organisational strategies. • Training sessions also focused on general strategies outside of therapy. Caregivers were involved in	• Participants met therapist(s) to select a goal area from the following: Depression, Anxiety, Anger/Irritability or Social Issues. • Implementation intentions were created by identifying responses that would promote goal attainment. • A message schedule was negotiated with each participant to determine when the SMS texts (with the implementation intentions) would be delivered. • Participants asked to rehearse messages by reading them at least 3 times	• During the first therapy session, a home exercise programme was developed by an OT with the participant, in line with usual practice. • An iPad was used to video the participant performing their home exercise programme with a commentary. • A reminder/ from the OT alarm was set up to provide both a visual and audio daily exercise cue. • Videos updated throughout the programme upon review.

		each working day. They did not occur within 30 minutes of each other.	speed by 5%. When participants were able to maintain this speed for more than 1 minute, they were asked to maintain the speed on their own by gradually turning down the volume of the metronome application until it was muted.	the training sessions where possible.	and reply with a brief phrase so that these could then be logged as received or 'processed'. • After 8 weeks of receiving messages, participant goal attainment was reassessed using GAS.	• Participants asked to complete their exercises for 4 weeks.
Frequency, duration, intensity and fidelity of implementation.	• Total training time was 16 hours with a therapist. • Initial training took between 2-6, 30 minute sessions. Frequency of training sessions varied between 2 times/week and 2 times/month. • Most participants received 30-60 minutes of training each week. • The frequency and intensity of training sessions varied, as this was dependent on routine procedures at the rehabilitation centre, and the specific needs of the individual. • PDA user interface was standardised for all participants as PEAT completely took over the device, meaning individuals could not switch to the Windows environment, thus avoiding confusion.	• The training period depended the individual and their knowledge/abilities to understand the intervention. • Participants received 2 training sessions that lasted between 90 and 120 minutes.	• Participants in the RAS group received 15 sessions of gait training for 30 minutes, three times per week (i.e. 90 minutes per week). • Participants also received 30 minutes of conventional therapy twice a day, 5 times per week. • Conventional therapy was defined as 'one-on-one neurodevelopmental therapy between a patient and a therapist'.	• OT chose the appropriate PDA for the participant from the selection based on their patient's experience with computer platforms/PDAs in the past. • Five structured training modules provided by OT over 8 weeks, with participants taking as long as needed to acquire the skills. • The timing, frequency and duration of the training sessions were consistent, with usual practice in the brain injury unit. • OTs kept records of number, duration and content of training sessions on paper data collection forms.	• A structured protocol was used to develop implementation intentions relevant to participants' specific goals. • Protocol was developed for the study and based on previous literature. • The implementation intention messages were delivered by SMS text over an 8 week period. • The number of daily messages varied between participants (5-7).	• Exercise programmes were based on the National Stroke Foundation Clinical Guidelines. • Content varied depending on individual deficits, as did the number of exercises and number of recommended sessions each day. • A typical recommendation was 1-2 times per day. • Participants used the iPad for 4 weeks.
Tailoring and modifications	• Following initial training, content of remainder of training course was tailored to the patients' specific needs. • PEAT software can be tailored to the individual and users had the control to alter the way they are cued at beginning and/or end of a task.	Not mentioned.	Not mentioned.	The technology changed during the period of the trial.	• A schedule was negotiated with participant as to when messages would be delivered. • Participants had the choice to receive messages on their mobile phone via text, voice or email. Participants' own words were used for the implementation intentions.	• Each participant had an individualised exercise programme which was recorded specifically for them. • Modifications were made to the programme if necessary when the participant was reviewed.

Appendix 7: Primary outcome data from included studies

Study ID	De Joode, 2013[6]	Gracey, 2017[11]	Kim, 2012[7]	Lannin, 2014[10]	Hart, 2017[8]	Emmerson, 2017[9]
Functional Outcomes	**Goal Attainment Scaling (GAS) Total** Outcomes at 16-hours post-treatment (between baseline T0 and T2): *Intervention*; mean increase 45.2 points (SD=32.8), p<0.001. *Control*; mean increase 36.7 points (SD= 15.6), p<0.001. Intervention vs. control at T2; p>0.5. **Frenchay Activities Index (FAI)** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 23, SD=7.6 (19.3 at baseline), *Control*; mean 20.9, SD=7.3 (23.4 at baseline). - Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 25.6, SD=7.4. *Control*; mean 24.3, SD=8.0.	**Intention Attainment** - Outcomes at 6 weeks following intervention phase 2 (intention to treat): *Intervention*: mean 0.64, SD=0.17. *Control*: mean 0.63, SD=0.21. Mean difference 0.01, 95% CI (-0.09-0.11), p=0.87. Missing values intervention n=4, control n=3. - **Mean daily goals achieved (non-phone intentions)** - Outcomes at 6 weeks following intervention phase 2 (intention to treat): *Intervention*: 0.85, SD=0.13. *Control*: 0.83, SD=0.17. Mean difference 0.05, 95% CI (-0.06-0.10), p=0.62. Missing values intervention n=4, control n=3.	**Functional Ambulation Category (FAC)** Outcomes following 15 hours training: *Intervention*; 4.33 (baseline 3.00), p<0.05*. *Control*; 4.56 (baseline 3.67), p<0.05*.	**Goal Attainment Scaling (GAS) Total** Outcomes at 8 weeks: *Intervention*; 53.9 points, SD=16.4 (baseline 14.1). Mean difference within group 45.3, 95% CI (39.1-51.3). *Control*; 54 points, SD=16.4 (baseline 15.4). Mean difference within group 38.4, 95% CI (31.5-45.4). Intervention vs. control (between groups): mean difference 6.3, 95% CI (-2.7-15.4), p=0.165 **GAS functional memory failures goal** Outcomes at 8 weeks: *Intervention*; 53 points, SD=5.2 (baseline 41). Mean difference within group 11.9, 95% CI (9.4-14.5). *Control*; 49.5 points, SD=5.9 (baseline 41.7). Mean difference within group 7.8, 95% CI (5.02-10.6). Intervention vs. control (between groups): mean difference 1.6, 95% CI (1.0-2.2), p=0.0001***	**Goal Attainment Scaling (GAS)** - No significant differences in self-reported GAS change scores between groups at 8-weeks post-intervention. - One participant reported no change, one reported +1, one +2 and one +3. - No significant difference between groups on GAS reported by participant's nominated person (significant other): Mann-Whitney U=4.5, p=1.0	**Wolf Motor Function Test** Outcomes at 4 weeks: Mean time (seconds) *Intervention;* 33, SD=37 (baseline 39). *Control*; 45, SD=44 (baseline 49). Mean difference between group -5, 95% CI (-11-1); p=0.101 Functional score *Intervention;* 3.2, SD=1.4 (baseline 3.1). *Control*; 3.0, SD=1.6 (baseline 2.8). Mean difference between group 0.1, 95% CI (-0.1-0.3); p=0.454
Quality of Life	**MOS Short Form health survey (SF-36): Physical functioning** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 43.9, SD=9.9 (44.7 at baseline). *Control*; mean 45.6, SD=7.2 (45.7 at baseline). Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 46.7, SD=8.4. *Control*; mean 48.1, SD=12.1. **SF-36: Mental functioning** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 39.6, SD=13.2 (38.6 at baseline). *Control*; mean 34.8, SD=13.3 (35.5 at baseline). Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 36.9, SD=12.2. *Control*; mean 35.5, SD=11.6. **Life Satisfaction Questionnaire (LISAT-9)**	No measure.	No measure.	No measure.	No measure.	No measure.

	- Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 39.2, SD=6.7 (40.4 at baseline). *Control*; mean 32.3, SD=7.8 (33.9 at baseline). Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 40.1, SD=5.3. *Control*; mean 32.6, SD=6.1.					
Independence	No measure.	No measure.	No measure.	No measure.	No measure.	No measure.
Fatigue	No measure.	No measure.	No measure.	No measure.	No measure.	No measure.

Appendix 8: Secondary outcome data from included studies

Study ID	De Joode, 2013	Gracey, 2017	Kim, 2012	Lannin, 2014	Hart, 2017	Emmerson, 2017[9]
Psychological function	**General perceived self-efficacy scale (GSES)** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 25.0, SD=6.7 (26.3 at baseline), *Control*; mean 25.3, SD=6.4 (26.5 at baseline). - Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 25.9, SD=6.5. *Control*; mean 25.2, SD=6.2. **Centre for Epidemiologic Studies Depression Scale (CES-D)** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 18.0, SD=8.9 (18.2 at baseline), *Control*; mean 20.2, SD=6.2 (19.9 at baseline). - Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 19.3, SD=7.8. *Control*; mean 19.0, SD=7.7.	**Profile of Mood States total mood disturbance (POMS-MD)** - Outcomes at 6 weeks following intervention phase 2 (per protocol): *Intervention*: mean -0.55, SD=25.6 *Control*: mean 2.83, SD=20.3. Mean difference 3.38, 95% CI (-8.78-15.54), p=0.58. Missing values intervention n=0, control n=1. - Outcomes at 6 weeks following intervention phase 2 (intention to treat): *Intervention*: mean 47.2, SD=40.6 *Control*: mean 47.3, SD=37.9. Mean difference -0.02, 95% CI (-19.37-19.34), p=1.00. Missing values intervention n=2, control n=2.	No measure.	No measure.	**Brief Symptom Inventory (BSI) Depression Scale** - Outcomes at 8 weeks post-intervention. *Intervention*: mean 53.2, SD=7.9. *Control*: mean 52.5, SD=11.9. F=0.3, not significant. **BSI Anxiety Scale** - Outcomes at 8 weeks post-intervention. *Intervention*: mean 52.3, SD=14.7. *Control*: mean 46.5, SD=10.4. F=0.3, not significant.	No measure.
Cognitive function	**Cognitive Failure Questionnaire (CFQ)** - Outcomes at 16-hours post-treatment (T2): *Intervention*; mean 42.2, SD= 15.9 (45.8 at baseline), *Control*; mean 49.2, SD= 14.8 (49.1 at baseline). - Outcomes at 4-6 months following 16-hour treatment (T3): *Intervention*; mean 48.4, SD=10.6. *Control*; mean 45.4, SD=15.1.	No measure.	No measure.	**Memory Functioning Questionnaire (MFQ): Retrospective memory functioning** - Outcomes at 8 weeks: *Intervention*; 15.8, SD=9.7 (baseline 12.5). Mean difference within group 3.2, 95% CI (-0.5-7.0). *Control*; 12, SD=6.1 (baseline 13.4). Mean difference within group -1.4, 95% CI (-3.9-1.1). - Intervention vs. control (between groups): mean difference 4.3, 95% CI (1.6-8.4), p=0.042 **MFQ: Mneumonic usage subtest** - Outcomes at 8 weeks: *Intervention*; 24, SD=10 (baseline 31). Mean difference within group -6.9, 95% CI (-12.8-1.1). *Control*; 25, SD=7 (baseline 26). Mean difference within group-1, 95% CI (-4.4-2.2). - Intervention vs. control (between groups): mean difference -2.7, 95% CI (-8.1-2.6), p=0.301	No measure.	No measure.
Satisfaction & use of intervention	- Outcome at T3 (4-6 months following 16-hour treatment): 57.1% intervention group chose to continue PDA or smartphone use; 76.9% control group chose to continue using paper aid. Three participants in control group (23.1%) stated they would consider buying PEAT software (intervention) or a different PDA or smartphone system.	No measure.	No measure.	- Outcomes at 8 weeks: 14/21 of intervention participants were still using the PDA daily (67%). 3/21 reported they were no longer using at all (14%).	No measure.	Outcomes at 4 weeks: - *How easy was it to follow instructions?* Very easy: *intervention* n=12/27; *control* n=11/37. Very difficult: *intervention* n=2/27; *control* n=1/37; p=0452. Intervention v control p=0.452 - *Did you remember home exercises?*

	- Intervention group vs. control group satisfaction not significant, x^2 (1, 34) = 1.4, p =0.24. Reasons for participants not to continue PDA use were too expensive to buy for themselves (19.0%) or preferred another or cheaper aid (23.8%).					Remembered all the time: *intervention* n=17/27; *control* n=17/37. Forgot all the time: *intervention* n=1/27; *control* n=0/37; p=0452. Intervention v control p=0.485 - *Did you enjoy home exercises?* Always: *intervention* n=8/27; *control* n=6/37. Never: *intervention* n=1/27; *control* n=1/37; p=0864.
Social participation & function	No measure.	No measure.	No measure.	No measure.	**Participation Assessment with Recombined Tools-Objective (PART-O): Social Relations (self-report)** - Outcomes at 8 weeks post-intervention. *Intervention*: mean 2.3, SD=0.6. *Control*: mean 1.1, SD=0.7. F=13.6, p=0.01, η^2=0.09. **PART-O: Out and About (self-report)** - Outcomes at 8 weeks post-intervention. *Intervention*: mean 1.6, SD=0.6. *Control*: mean 1.2, SD=0.3. F=14.7, p=0.009, η^2=0.27. **PART-O: Productivity (self-report)** - Outcomes at 8 weeks post-intervention. *Intervention*: mean 1.7, SD=0.5. *Control*: mean 0.6, SD=0.2. F=0, not significant.	No measure.

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