Institution: Imperial College London

Unit of Assessment: 04 Psychology, Psychiatry and Neuroscience

Title of case study: GripAble™: enabling self-directed arm rehabilitation

Period when the underpinning research was undertaken: 2014 - 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Paul Bentley	Senior Clinical Research Fellow, Hon Consultant Neurologist	2008 - present
Etienne Burdet	Professor of Human Robotics, Bioengineering	2014 - 2020

Period when the claimed impact occurred: 2018 - 2020

Is this case study continued from a case study submitted in 2014? No

1. Summary of the impact (indicative maximum 120/100 words)

Upper limb disability due to neurological or musculoskeletal disease affects millions of people in the UK and worldwide. Physical therapy is beneficial, but requires high-intensity, repetitive training. Conventional physical therapy involves direct interactions between therapist and patient, which limits its delivery. To overcome this and reduce costs for upper limb physical therapy, Imperial Researchers invented 'GripAble™', a low-cost portable device that enables *self-directed* arm movement training. The Imperial College researchers commercialised it in 2018 as GripAble, Ltd., [redacted] It is now the most widely adopted technology in the UK upper limb therapy market.

2. Underpinning research (indicative maximum 500 words)

Arm and hand weakness after stroke should be treated with repetitive task training. However, conventional delivery in 1:1 sessions between patients and physical therapists limits the intensity with which this can be done. Robotic tools enabling self-directed therapy have long held promise to supplement arm training and reduce the need for continuous, direct interactions between physical therapists and patients, but previous arm rehabilitation robots were cumbersome and costly, limiting their practical application.

Addressing this, research at Imperial College showed that small robotic devices able to promote functional hand interactions with real objects provide effective rehabilitation both for the hand and the entire arm (1). The Imperial team also showed that arm weakness after stroke arises not only as a consequence of brain injury affecting motor pathways, but also from damage to cognitive networks, which can be trained using grip-control software games (2).

Combining these insights, the researchers developed a small, simple, mobile device ('GripAble™'), which "gamifies" physical therapy exercises for improving functional arm and hand movements. Product design was optimised over several years using a patient-centred "double-diamond" process in collaboration with medical device designers from the Helen Hamlyn Centre, Royal College of Art. This involved hundreds of patients with varying arm-disabilities testing multiple iterations of hardware and software prototypes, in order to maximise the range of patients that could benefit from the innovation.

The device is innovative. It has a unique patented sensor mechanism (paired cantilevers) that enables highly-sensitive and robust force measurement, whilst also mimicking the flexibility of everyday objects. This flexible sensor design improves comfort, motivation and motor performance compared to standard rigid sensors (3). The device has also been tailored to the needs of physical therapists and allows for a range of exercises and remote assessments of both upper (shoulder/elbow) and lower (hand/wrist) arm.

Clinical studies have investigated accessibility and usability of GripAble™ in real world scenarios. GripAble™ was able to be used by 93% of unselected stroke patients with arm weakness (4). This makes it the most highly accessible technology for self-directed training in natural cohorts of stroke survivors with arm weakness.

Exercise intensity is one of the strongest modifiable factors determining physical recovery after stroke and providing the device to stroke inpatients (plus a single training session) increases the total time they perform arm exercises 2-fold, and exercise repetition counts 10-fold, compared to standard care (5). This study is the first clinical trial to show that a self-directed arm rehabilitation technology increases exercise intensity among *unselected* stroke patients, including those with severe arm disability and co-existing cognitive impairment, relative to standard care.

Gripable™ also has been employed in research studies investigating optimal exercise training schedules for motor learning in stroke and in people with cerebral palsy. Motivation and performance gains using Gripable™ were shown to improve further through collaborative exercises between abled and disabled people relative to training alone (6). This discovery was the basis for a £1,100,000 NIHR award which is developing the world's first "Online Social Physiotherapy Network", which is enabling directly interactive arm exercises between remotely located patients with each other or with healthy volunteers using either Gripable™ or standard mobile phones/tablets.

3. References to the research (indicative maximum of six references)

(1) Lambercy, O., Dovat, L., Yun, H., Wee, S.K., Kuah, C.W.K., Chua, K.S.G., Gassert, R., Milner, T.E., Chee Teo, C.L., Burdet, E. (2011). Effects of a robot-assisted training of grasp and pronation/supination in chronic stroke: a pilot study. *J Neuroeng Rehabil*; 8:63. DOI.

(2) Rinne, P., Hassan, M., Fernandes, C., Han, E., Hennessy, E., Waldman, A., Sharma, P., Soto, D., Leech, R., Malhotra, P.A., Bentley, P. (2018). Motor dexterity and strength depend upon integrity of the attention-control system. *Proc Natl Acad Sci USA*; 115(3):E536-E545. DOI.

(3) Mace, M., Rinne, P., Liardon, J.L., Uhomoibhi, C., Bentley, P., Burdet, E. (2017). Elasticity improves handgrip performance and user experience during visuomotor control. *R Soc Open Sci*; 4(2):160961. DOI.

(4) Rinne, P., Mace, M., Nakornchai, T., Zimmerman, K., Fayer, S., Sharma, P., Liardon, J.L., Burdet, E., Bentley, P. (2016). Democratizing neurorehabilitation: how accessible are low-cost mobile-gaming technologies for self-rehabilitation of arm disability in stroke? *PLoS One*; 11(10):e0163413. DOI.

(5) Broderick, M., Bentley, P., Burridge, J., Burdet, E. (2020). Self-administered gaming exercises for stroke arm disability Increase exercise duration by more than two-fold and repetition more than ten-fold compared to standard care. *World Stroke Congress Abstracts*. *Int J Stroke*. 2020 Nov 15(1S) 255. DOI.

(6) Mace, M., Kinany, N., Rinne, P., Rayner, A., Bentley, P.*, Burdet, E.* (2017). Balancing the playing field: collaborative gaming for physical training. *J Neuroeng Rehabil*; 14(1):116. (*co-corresponding authors). DOI.

4. Details of the impact (indicative maximum 750 words)

Functional impairments of arm and hand movement comprise the commonest stroke related disabilities, affecting 75% of the 100,000 new stroke cases each year in the UK. Guidance from the Royal College of Physicians in 2016 and National Institute for Health and Care Excellence (NICE) in 2013 recommended that arm weakness after stroke should be treated with repetitive task training, outcomes of which are dependent on frequency and repetition. However, the amount of upper limb therapy provided on the NHS is markedly less than what is known to be effective because of inadequate provision of therapists delivering services [**A**]. Although UK NICE guidelines recommend at least 45 minutes of therapy per day for meaningful improvements after a stroke, the 2019-20 UK national stroke audit showed that actual inpatient therapy is an average 25 minutes per day, which decreases still further when patients were discharged [**B**].

Conventional physical rehabilitation requires 1:1 interactions between a physical therapist and patient and therefore is expensive to deliver and limited by staff time. Service provision could be improved for better patient outcomes using technologies enabling patient-directed rehabilitation. This is not a new idea, but previous rehabilitation technologies were not widely adopted because of unit costs, complexity, and special site requirements. To address these challenges, researchers at Imperial College developed 'GripAble™', a low-cost, accessible, mobile patient-directed upper limb rehabilitation device. GripAble™ was designed to enable a broad range of patients with arm disability to engage in self-directed arm training without the need for professional supervision, including those with severe weakness and cognitive impairment. It can be used by patients in their homes, as well as in hospitals, with the option that home performance can be monitored by physical therapists or doctors logging in remotely.

GripAble™ [**C**] prototypes were used by therapists at Imperial College NHS Healthcare Trust and Imperial Private Healthcare to supplement standard upper rehabitation exercises for stroke and other neurological causes of arm weakness from early 2019. By 2020, the system was being offered to all patients with arm weakness as part of standard of care therapy; 10-20 new patients per month have been using the protocol system for part or the entirety of their hospital stay and, in selected cases, for up to several months post-discharge.

In the same year, Imperial College researchers founded Gripable Ltd to manufacture, distribute and further develop the system. [redacted]

Gripable Ltd. launched its first Gripable™ product line in Summer 2020. By the end of 2020, Gripable™ was deployed to neurological and rehabilitation centres across 17 countries; [redacted] including the Royal Hospital for Neurodisability, North-West London, and Aldebourne Rehabilitation Centres, King's College Hospital, St Georges NHS Trusts, Cereneo (Switzerland) [**D**], Hobbs [**E**], BMI, HCA, and 12 Centres in the USA, India, Canada, Singapore, S Korea, Japan, UAE, and Qatar. Measured in terms of units in use, Gripable™ became the most adopted technology in the UK for upper limb rehabilitation by the end of 2020. It also is the only rehabilitation system shown to allow patients continued use in the transition from hospital-based rehabilitation to home and fully self-directed rehabitation [**C**].

[redacted] This demonstrates that as barriers to conventional physiotherapy increased and the number of supervised rehabilitation sessions dramatically decreased, GripAble™ enabled patients to continue their essential rehabilitation

exercises at home supervised remotely by their therapists using the patient's online performance records.

While thus far GripAble™ has predominantly benefited stroke patients, it is now increasingly used in the treatment of a wider range of conditions. GripAble™'s digital register currently includes [redacted] patients with a diagnosis of multiple sclerosis, traumatic brain or spinal cord injury, peripheral neuropathy, Parkinson's disease, arthritis, sporting injuries or complex hand surgery [**C**]. Furthermore, at Great Ormond Street and the PACE Centre children with cerebral palsy and neurodevelopmental disorders are now using GripAble as part of their treatment.

The availability of GripAble™ has added to options for upper limb physical rehabilitation endorsed by the Association of Chartered Physiotherapists in Neurology [**F**]. The President of the Association, Prof. Jane Burridge wrote:

"[GripAble] fulfils a need for higher intensity, home-based, self-administered rehabilitation that cannot be practically met by increasing therapist numbers given NHS resource constraints… ACPIN fully support the translation of GripAble into routine clinical use and have actively supported dissemination of the evidence and information about the device."

GripAble™ also has had an impact on therapies recommended by other national rehabilitation information sites such as the UK's leading online disability lifestyle magazine (AbleMagazine) **[G]**. Use by Key Opinion Leaders and Rehabilitation Centres was highlighted by a Parliamentary Under Secretary of State at the Department of Health and Social Care [**H**].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[**A**] Repetitive task training can help recovery after stroke (2017). NIHR Alert. DOI.

[**B**] Stockley, R., Peel, R., Jarvis, K., et al. (2019). Current therapy for the upper limb after stroke: a cross-sectional survey of UK therapists. *BMJ Open*;9:e030262. DOI.

[**C**] Letter of Commercial Traction signed by Paul Rinne, CEO.

[**D**] https://www.cereneo.ch/your-rehabilitation/#rehabilitation-at-home
(World-leading Swiss neurorehabilitation centre features GripAble within its training schedule:" 11:00 Video call with the neurologist: A key element of your cereneo @ Home programme is the exchange with our neurologist who represents the network and knowledge of cereneo`s interprofessional team of experts. In this video call, the neurologist will share the latest results from your rehabilitation assessment and the data generated by your Gripable training device with you and discuss the suggested changes in your daily rehabilitation routine." Archived here.

[**E**] https://www.hobbsrehabilitation.co.uk/gripable.htm/
And https://twitter.com/HobbsRehab/status/983798826715746305/photo/1
(well-established UK network of 10 rehabilitation centres features GripAble within their training schedule). Archived here.

[**F**] https://www.acpin.net/
(GripAble is highlighted on the home page); https://gripable.co/tag/acpin/; letter from Prof. Jane Burridge, President of the Association Chartered Physiotherapists in Neurology.

[**G**] https://ablemagazine.co.uk/gripable-beating-the-rehabilitation-grind/ (Archived here).

[**H**] Key Opinion Leaders and Rehabilitation Centres:
https://twitter.com/nicolablackwood/status/1181947913011961857/photo/1 (archived here)
(Baroness Blackwood: Parliamentary Under Department of Health and Social Care [tweet: 09/10/19)

https://www.stroke.org.uk/research/research-events/amazing-brains-2019 (archived here).
Lecture by Jane Burridge features Gripable 9:20 – 10:10
https://youtu.be/8lFYbyPMlIQ (Archived here).