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Abstract

Purpose

Restoration of walking ability is a key goal to both stroke survivors and their therapists. However, the intensity and duration of rehabilitation available after stroke can be limited by service constraints; despite the potential for improvement which could reduce health service demands in the long run. The purpose of this paper is to present qualitative findings from a study that explored the acceptability of a haptic de vice aimed at improving walking as part of an extended intervention in stroke rehabilitation.

Design/methodology/approach

Pre-trial focus groups and post-trial interviews to assess the acceptability of Haptic Bracelets were undertaken with stroke survivors.

Findings

Five themes were identified as impacting on the acceptability of the Haptic Bracelet: potential for improving quality of life; relationships with technology; important features; concerns; response to trial and concentration. Participants were interested in the haptic bracelet and hoped it would provide them with more confidence making them: feel safer when walking; have greater ability to take bigger strides rather than little steps; a way to combat mistakes participants reported making due to tiredness and reduced pain in knees and hips.

Originality/value

Haptic Bracelets are an innovative development in the field of rhythmic cueing and stroke rehabilitation. The haptic bracelets also overcome problems encountered with established audio based cueing, as their use is not affected by external environmental noise.

Introduction

Globally, stroke prevention and rehabilitation are priority areas, since 'stroke is the second leading cause of death and a major cause of disability worldwide' (Katan and Luft 2018 p.208). However, the incidence and mortality of stroke varies considerably between countries, affected by issues such as access to medical care, levels of medical literacy, and problems of concordance with preventative and treatment interventions (Katan and Luft, 2018). High incidences of stroke and cardiovascular risk have been identified as particularly problematic in low- and middle-income countries, and in regions such as Russia, China, India and Asia (Katan and Luft, 2018), In the world generally, and in such areas in particular, cost-effective solutions for stroke rehabilitation could make an important contribution. Paradoxically, while prevention and reduction of cardiovascular disease and stroke are generally considered priority areas for public health interventions, the evidence suggests that, in practice, stroke is often treated as a lower priority for clinical services and research than other diseases with a similar or lower public health impact (Thrift et al 2014). This apparent anomaly may be related to cost issues and treatment outcomes, given that stroke rehabilitation typically accounts for a large percentage of heath care budgets, as documented in the case of, for example, the UK National Health Service (Pennycott et al., 2012). Against this backdrop, and in the context of a realistic view of the impact of a stroke to individuals and their supporters this paper presents research findings from a study where a novel assistive technology was used to intervene with stroke survivors living with a range of post stroke disabilities.

In the UK where the research reported in this paper was undertaken, around 100,000 people will have a stroke this year (The Stroke Association, 2018). While advances in medical treatment mean that many people are more likely to survive stroke and have improved outcomes, impaired ability for walking, and specifically walking in the community, continues to be a significant problem for many stroke survivors (see for example Smulders et al, 2012). This results in persistent restrictions in mobility for many stroke survivors, contributing to a significant reduction in their quality of life and participation (Bohannon et al., 1991; Ferreira et al., 2015). Common mobility restrictions typically include temporal asymmetry of walking, characterised by differences in limb stance and swing limb time; with greater weight being taken on the side unaffected by the stroke, impaired balance and reduced walking speed (Bohannon et al., 1991). These impairments are associated with an increased risk of falls, fear of falling, difficulties returning to work and/or hobbies and precipitate and/or accelerate degeneration of the hip and knee joints on the side unaffected by stroke, producing pain and dysfunction and compounding mobility problems (Ferreira et al., 2015).

Restricted mobility in the community has been shown to contribute to social isolation, which is reported by over a third of people after stroke, in addition to poorer mental and physical health (Ferreira et al., 2015). Increased isolation is likely to lead to a loss of sense of self, greater carer burden and can produce other significant health conditions, with associated healthcare costs, secondary to a sedentary lifestyle. In this context, an adjunct to therapy, which improves outcomes, without necessarily increasing service costs, would clearly be desirable.

Rehabilitation After Stroke

The advent of new medical therapies mean that more people are surviving, and living for many years after a stroke, but the standard of treatment for stroke varies in the UK and globally (Ceornodolea et al., 2017; The Stroke Association, 2018). Variations in age, gender, social depravation, timely interventions and degree of physiological damage contribute to a position where two thirds of survivors leave hospital with a disability (The Stoke Association, 2018). This highlights the demand for timely and efficacious rehabilitation treatments that can improve key functions for people after stroke. However, such treatments will only be successful if they are welcomed by stroke survivors, their supporters and their rehabilitation team (Doughty and Appleby, 2016).

One established successful approach to gait rehabilitation uses audio based rhythmic cueing. This provides an audible cue which the user follows when walking (e.g. similar to marching to a musical beat). For example, this approach harnesses entrainment processes by which an individual can follow and reproduce rhythmical stimuli, for example, tapping along to a beat (Schaefer 2014). While approaches to rhythmic auditory cueing have been shown to be effective in improving walking symmetry after stroke (States et al 2009), their effectiveness can be limited in noisy environments such as when walking near a road on in a busy place. There are also circumstances where audio cueing may be undesirable or unsuitable in cases where there is hearing loss, Using external audio cues can also create difficulties as individuals may not be able to differentiate which cue is for which leg (Wright et al., 2013), thus missing out on some potentially beneficial aspects of focusing attention and proprioception in gait rehabilitation. Providing a sensory stimulus using haptics is recognised to provide a useful training cue in groups with minimal sensory impairments (Thaut, 2007) Shull et al 2015) and unaffected by environmental noise .If this device can be developed to be acceptable to people after stroke, it may provide a valuable alternative for rehabilitation interventions that aim to improve mobility and wider quality of life after stroke.

The Haptic Device

As a potential solution, The Open University have developed a prototype wearable system for rhythmic cueing based on haptics (called the Haptic Bracelets (Georgiou 2018), which has been shown to be effective in pilot studies (Holland et al., 2014, 2015; 2018; Visi et al 2017). Studies with brain injury and stroke survivors showed an immediate (though not necessarily lasting) improvement of temporal gait characteristics when asked to walk while trying to synchronise their steps to the rhythm of the haptic cueing (Georgiou 2018, Georgiou et al 2020a). Some improvements (in relation to gait asymmetry) over baseline occurred immediately after, rather than during, haptic cueing suggesting some lasting effect (Georgiou

2018, Georgiou et al. 2020a). Similar immediate benefits for walking were also observed in case study with individuals with Huntington's disease – benefits which may potentially extend the period of their independent mobility (Georgiou et al. 2020b).

The Haptic Bracelets, which grew out of earlier research with musicians (Bouwer et al. 2013), are designed to work ideally in pairs with one device worn on the shank of each leg at ankle level (though other modes of use are possible – for example a single device worn on the wrist). Each device contains a microcontroller, wi-fi capabilities and precise vibrotactiles capable of delivering the rhythmic haptic cueing on alternate legs. Each device also contains an *inertial measurement unit (IMU)* which can monitor and record data relevant to the wearer's gait characteristics. These data are logged for offline analysis, aiming to help physiotherapists and health practitioners understand how the patient is performing during rehabilitation sessions using the devices (see Chapter 5 of Georgiou 2018 for full technical specifications).

<Insert picture 1 here>

In many contexts, cues provided through the sense of touch by means of a vibrotactile device (haptic cues) are well suited to walking in the community as they can provide a consistent regular cue without being affected by environmental noise. Both haptic and audio cues use the same entrainment processes within the central nervous system (Angelis et al, 2013) which is the mechanism by which an individual can follow and reproduce rhythmical stimuli, for example, tapping along to a beat. However, as the Haptic Bracelets are meant to be used as wearable devices for gait rehabilitation, it is important their design reflects the needs of the actual users who should be using them. Some design issues that had to do with the devices' wearability were tackled during lab testing and lessons learned from early small scale pilots (Holland et al., 2015) While initial lab testing and pilot studies raised some interesting questions regarding the design and placement of the devices from the participant's point of view, more in-depth dialogue with potential users was desired. Therefore this present study was organised aiming to engage with stroke survivors and identify aspects of the design that the Haptic Bracelets may need improvement on and to assess their acceptability as wearable devices for gait rehabilitation.

Method

Aims

This research was part of a larger project to improve gait symmetry after stroke and related neurological conditions; findings related to this wider research are explored elsewhere (Holland et al., 2014; 2015; Georgiou et al., 2020a, 2020b). A pragmatic but rigorous approach was selected for the study that is the focus of this paper as we were not aiming to generate theory but more to look at the utility and insights of the Haptic Bracelets for stroke survivors (Cheesboro and Borisoff, 2007). Drawing on this approach our aims were then to a) gain practical insights into the acceptability of the prototype in stroke patients and b) explore the wearability, aesthetics, mode of use, and functionality of the device.

Participants and Data Collection

Phase One

Phase one data was collected at two focus groups which were held during June and July 2016. The aim of the focus groups was to examine the opinions of stroke survivors (two groups of four participants) on the development of the haptic device. As this was a pragmatic qualitative study of the Haptic Bracelets convenience sampling was used and there was no attempt to control participant recruitment between the two phases of this study. Recruitment was solely based on participant interest and motivation to participate. Potential participants were contacted through the research team's contacts at stroke support groups and local clinical networks. In total, eight stroke survivors self-selected and took part in phase 1 of the study. In order to ensure participant understanding of the system, focus group participants were shown a short video presentation demonstrating the haptic device in use, see https://www.youtube.com/watch?v=FefDOXtCfGM. Participants were asked to give comments and thoughts on the Haptic device they had observed. These comments were noted and the stroke patients focus groups concluded with a Diamond Nine card sorting activity (Clark, 2012). Participants were asked to identify nine factors that they considered important in the development of the haptic device. They were then asked, as a group, to rank the priorities from most important to least important. They placed the cards on the table identifying the highest priority, two high priorities, three middle priorities, two lower priorities and the lowest priority (so that the cards became a diamond shape). The discussion that took place during this activity highlighted justifications for choices and discussion of any disagreements.

Phase Two

Phase two data was collected seven months later (January and February 2017) when seven self-selecting participants attended a university movement laboratory to trial the haptic device. Participants were recruited from the Stroke Association support groups and from participants from the previous focus groups who had expressed interest in wanting to trial the device. After completing a rhythm detection test to ensure that they could respond to the beat, participants took part in a trial of the device in which they were asked to walk the length of a 10-metre runway under the following three conditions in turn: before using the device (six times); with the device operating (six times and after using the device (a final six times). Once completed, short semi-structured interviews were carried out. The interviews lasted 10-15 minutes; they were intentionally kept short because most of the participants had undertaken a significant journey to travel to the university movement laboratory and had then taken part in more walking than they had done for a considerable time and were expected to be fatigued. The participants were interviewed by an experienced qualitative researcher with support from another member of the research team. While fatigue following the gait trial followed by an interview can impact on data collection; in the context of this study it was important to gather the participants thoughts and experiences at the time that they actually used the Haptic Bracelet. Participants were aware of the study processes in advance of the day and were provided with refreshments and travel support. The details of these participants are given in Table 1. It must be noted that the research team did not have access to the participants medical records so were unable to determine the participants type of stroke.

<Insert Table 1 about here>

Ethics

The project was approved a university ethics committee in the North West of England (Ethics approval 1368). Participants responded to requests to take part, completed consent forms and were able to withdraw from the study at any time. All data has been anonymised.

Analysis

Interviews and focus groups were transcribed verbatim and both phases were combined and analysed thematically (Braun and Clarke, 2006) alongside the results of and discussion around the Diamond Nine activity. Drawing on the 'Diamond 9' approach in the focus groups the stroke survivors prioritised their key requirements for the development of the Haptic Bracelet. The data from the focus groups was combined and then added to following the one-to-one interviews in Phase Two of the research when new priorities were added. These priorities are detailed in Table 2. The use of mixed qualitative methods in this way is supported by Morse (2010) who argues that mixed qualitative design, data can be pooled as categories or themes are constructed to increase to gain increase the depth, scope and usefulness of understandings within a research project.

<Insert Table 2 about here>

Results

Drawing on the focus group and interview data, two members of the research team (SC and JT) separately reviewed the data to identify key issues identified by participants across both data sets. Both members undertaking the analysis of the qualitative data were experienced qualitative researchers with a published track record in qualitative data collection and analysis. The data analysis was an iterative process and initial themes and categories were developed until five global themes were finally identified: Potential for Improving Quality of Life; Relationships with Technology; Important Features; Concerns, Response to Trial; and Concentration.

Potential for Improving Quality of Life

Participants spoke about how their stroke had affected their quality of life which consequently had led to their interest in the Haptic Bracelets. Participants talked about their difficulties with walking and mentioned: balance; leg swinging; leg stiffening in cold weather; loss of feeling in feet; negotiating stairs; turning; and negotiating uneven ground. Participants explained how these difficulties with walking impact on daily activities, confidence and quality of life. Often, they adapt their behaviour to deal with the problems; they have to think about every trip they make and modify the activities they take part in or make complex plans to make sure they feel confident.

"My workplace is only a bus stop from my house but if my husband couldn't come and pick me up I have to use the bus but I couldn't get off at my bus stop because it's a really busy road to cross the road so I have to think about another bus stop, get off and just try to cross

the road. I was easier to cross the road at the next stop." (Phase One: Focus Group 1 Participant)

"I think there are certain situations, I go to football matches and like you say unless you've got somebody with you I won't go into the stands because they don't have handrails when you come down the steps, and there is no way I can free walk down steps, I'm just so unstable. So I would only go if I had help". (Phase One: Focus Group 2 Participant)

Although participants want the device for use out of the home, they said they would like to try it in the home initially to build confidence. Participants hoped the product would provide them with: more confidence and make them feel safer when walking; greater ability to take bigger strides rather than little steps; a way to combat the 'mistakes' participants reported making due to tiredness; reduced pain (knees, hips).

Relationship with Technology

In order to ascertain how receptive to new technology participants were likely to be, the participants were guided to talk about their relationship with technology. Participants were asked about what kinds of home-based devices they use on a regular basis and about their views on health technology. Across the two focus groups, six participants used mobile phones, two did not. All used a computer/laptop at home but mostly in a limited way. There were a number of comments about not being 'well up' on technology. The majority of participants were retired and some said they had lost touch a bit. However, the general sense was that participants were happy to try new things that might be helpful.

When asked about wearable technology the participants in the focus groups and interviews knew of Fitbits and of stop watches and/or GPS watches for runners. Some concerns were mentioned in both groups about whether wearable technology would interfere with other health conditions (e.g. one participant mentioned a pacemaker and another mentioned concern that devices could spark off a seizure for people with epilepsy).

However, in the post-trial interviews one participant noted that not much technology had been around when they had their stroke. When asked whether the technology had made a difference to their walking and whether they could imagine using the technology in the trial they said:

Oh yes, I felt I was sort of staying in and the more I got confident I was stepping out more as well which we commented on didn't we. (He says laughing) You know the first couple of times I did it I was feeling my feet if you like and walking along trying to remember the rhythm and then when we got the sound off and that and I found it was very helpful to me. Certainly I can see a future for it with stroke survivors (Phase 2: Participant 4).

Interviewer
Ok, well that kind of leads onto my next question – can you imagine would you use something like that?

Yes *I certainly would have if it had been available, what seven years ago I came out and not a lot of things there for me to do you see. I mean we found our own things like we got that thing for getting my arms exercised a pulley stuck into the door so that motivated me to get the right arm moving (Phase 2: Participant 4).*

In contrast one of the trial participants expressed some concern about the use of technology in stroke rehabilitation saying:

With a stroke survivor the less technology involved that they've got to deal with the better (Phase 2: Participant 6)

Important Features

As shown in Table 2, the top priority for the stroke survivors was that the device worked well and consequently, many participants pointed out that in terms of aesthetics, if the benefits to patients were there, looks were not that important as people in the phase 2 trial commented:

It wouldn't matter to me whatsoever if it helped me to make things easier and more how it was before or to stop pain, anything that helped I wouldn't care what it looked like (Phase 2: Participant 6

No I'm just thinking, if it does the job for the patient it doesn't matter what it looks like or what it sounds like (Phase 2: Participant 7).

No suggestion on looks because it isn't a beauty parade, it's about the functionality of it (Phase 2 Participant 3)

However, some participants felt that a more compact Haptic Bracelet would be more appealing with one noting:

Yes it was big and chunky so that people could actually see it and then when you are walking they've got their eyes on you, you know what I mean. If it's nice and compact I think it would be great (Participant 2)

Participants discussed whether they thought the device should be given to them pre-programmed by a physiotherapist without having the ability to adjust its settings, or whether they would prefer to be able to make adjustments themselves but as shown in Table 2, this was fairly low down on the list of priorities and most participants wanted to be able to have the control of the device themselves. Participants spoke of the need for them to have control of the device so they could adjust it to their needs on a day-to-day basis, as one person said:

I think if the person sets it [rather than physio] because it depends on how they feel day by day, they might feel tired one day so they don't want to walk fast or anything but on another day they are fine and they want to walk a little bit faster or further (Phase 2: Participant 7).

Another participant commented:

Yes if it can work that way that the rhythm you are trying to operate controls it, I think that would be equally as good, but certainly one where you could control the rhythm yourself. I think it's got to be one or both. It's along those lines certainly. But certainly at the beginning if it's somebody that's first starting to walk after strokes they will be walking and shuffling a bit rather than stepping out so you need a slower rhythm obviously there than possibly later (Participant 4).

Concerns:

Stroke survivors expressed concerns about how the device might adapt when they tire; they wanted to know if the vibrating would take tiring into account (e.g. a walk home from the shops may need to be at a slower pace than a walk to the shops).

Participants also expressed a concern about only having used the haptic device in a controlled environment, so for wider use wanted to it elsewhere and in their own time, for example one participant said:

It felt a bit strange because all the time I am thinking of my epilepsy so it's strange for that but I felt it. I would like to ideally take it home for a week and do twenty minutes walk outside, ideally, but that's the prototype (Participant 1)

A few participants expressed concern about the aesthetics of the device, that they wouldn't want to wear a device on their leg while wearing a skirt or that they were concerned that it might look like an electronic tag.

I think if it looks like a tag, like you've been tagged and you have a curfew and people would be thinking you know. It could be designed a bit better maybe. (Phase One: Focus Group 1 Participant)

Stroke Survivors Response to Trial

The main concern of both the research team and the participants was whether the device had been effective. At the time of interview, participants were not aware of their results so the following comments on the effectiveness of the device were their perceptions on how well it had worked and if they thought their walking had improved. Overall the participants were positive about their experiences of using the Haptic Bracelet:

I'm used to using a walking stick and I didn't use the walking stick inside when I was walking and I felt a lot stronger…walking in there without the stick…..it made a difference in that I had a bit more confidence. I felt confident without the stick (Phase 2: Participant 2).

I did fine. As I say I wasn't aware you know, from the beeping noise when we went through the procedure to start with and then when I started walking I wasn't actually aware of anything.

Yet I felt it was quite rhythmic that I was going so I thought it was an excellent step forward if you like (Phase 2: Participant 8).

Participants explained their experiences of how easy it was for them to walk 'in time' with the beat with most participants expressing a view that it had taken some time to get used to it, it was a challenge, but they had enjoyed it.

Yes because it's made me think about slowing down, it's made me realise that slowing down is definitely what I've got to do, because by slowing down as well it made me think about the way I walk and it's obviously safer as well isn't it. But yes and trying to think about the beat obviously makes sense to do that and yes without this I wouldn't have done that (Phase 2: Participant 6).

In some cases the participants did not sense that the Haptic Bracelet was working, but their comments suggest that it might have been effective without them realising. For example, in the interview participants were asked – Where would you use it? Responses were given such as:

I could use it without any problem you know, if I'd got a good length of walking to do more or less in a straight line. I'm not sure how it would be if you weren't walking in a straight line in a controlled environment. If I was walking down a footpath, say at the side of the road where you tend to wander a little bit I'm not sure how much the rhythm would have been there then. , (Phase 2: Participant 3)

Another participant (Participant 5) felt he had not responded well to the haptic device saying:

Well its not good because I don't know where this – myself is ok but you it isn't good is it really.

Interviewer Give me a bit more, what not good:

My results.

Later on when asked if he felt the device made a difference to his walking he responded:

No

Other respondents commented that they felt the Haptic Bracelet would be of more use in an external environment saying:

*Not in the house no…..Because I don't think in the house there's rarely a time when I am walking any length, any distance, mostly I'm walking in a constrained environment where a lot of the concentration is not on the rhythm of walking, it's avoiding furniture and obstacles so I don't catch my feet in things when I'm walking. So that's why I wouldn't wear it in the house because the majority of movement around the house is just for short distances (*Phase 2: Participant 3*)*

Having experienced the device, most participants felt that it was not suitable to use in the house because the house is likely to already have some adaptations (e.g. handrails) making the device unnecessary and also because there was generally less opportunity to 'step out' in the house.

Concentration

A number of participants talked about concentration. For the device to be beneficial to people, a requirement was that stroke survivors could adapt to wearing it and still be able to carry on with other activities such as talking to companions, looking out for traffic and obstacles. Many of the participants talked about the concentration required in the sessions in the movement laboratory (this could, of course, be partly because of the experience of trying something new, in a new environment, with people they do not know). The following three participants highlighted issues with concentration:

Q - ….when you walked then did you walk on your own or were you walking with (research team member)?

Well [research team member] was behind me. I don't know. I was thinking of the beat (Phase 2: Participant 1).

I was really concentrating on it yes I think it was a case of trying to get my brain to appreciate what we were trying to do with it really. To me that was multi-tasking which is something that my brain can't do anymore (Phase 2: Participant 6)

I found it very interesting but when it came down to the vibration bit it was a bit disappointing as I couldn't feel anything through my left leg so I felt that my walking was more working on the memory than it was on the device. I was concentrating on responding to the right leg but I felt after a while that what was happening is I was anticipating the rhythm of doing it to my rhythm rather than to the device's rhythm. But overall, that's your question, the bottom line is overall interesting and I think it's helped me (Participant 3)

Discussion

The findings from the focus groups and trial of the Haptic Bracelet indicated that stoke survivors saw positive benefits to using this technology as part of their ongoing rehabilitation. More specifically, the findings indicated that participants saw potential benefits to their lives as people living with strokes. However, issues of confidence using new technologies, the look and feel of the Haptic Bracelet and user experiences in real world and rehabilitation settings were all noted as findings in this pilot study. In order for innovations such as the Haptic Bracelets to successfully make a difference to peoples' lives, they must then have to be welcomed and adopted by the patient. In further studies this means that demographic-related factors including :age, gender, ethnicity, occupation, income, family support and education, should be considered; as well as those relating to their appearance and usability. It should also be noted that the average age of our participants was slightly younger than the UK national age for stroke survivors. Which may have affected their responses to the Haptic Bracelet have to be considered as well as those relating to their appearance and usability. Cimperman et al (2013) identified predictors that play a role in perceptions of telemedicine services amongst older adults. They found that perceived usefulness, effort expectancy, social influence, perceived security, computer anxiety, facilitating conditions, and physicians' opinions all played a role in how well received telemedicine might be. Cimperman's (2013) work was also informed by the work of Venkatesh et al (2003) on the unified theory of acceptance and use of technology model where perceived usefulness, effort expectancy, social influence (the extent to which the user perceives that important others believe he or she should use the system) and facilitating conditions (the extent to which the user believed than an infrastructure exists to support the use of the system) are the key components to successful uptake of technology. With effort expectancy and perceived usefulness having a clear impact on acceptance, health-related ICT for the elderly should be kept simple and demonstrate substantial benefits (Heart and Kalderon, 2013).

With regards to the limitations and potential for impact of the study, the research team had to consider that participants volunteering for this research may have done so due to an interest in finding a solution that might improve their quality of life after stroke where other solutions had not been found. However, we recognise that motivation is a complex phenomenon and while stroke survivors may want to take part in initiatives that can improve quality of life. This is supported by the work of (Morris et al, 2017) who found that *beliefs about stroke cause, recovery, enjoyment and expectations of benefits influenced desire, or motivation to participate, beyond daily tasks* p314. In our study, participants' reports of the challenges they faced, variously concerning: trip planning; support needs; and lack of confidence — particularly when walking outside; may have made participants particularly receptive to learning about and trialling the Haptic Bracelet.

While not part of this study, the research team also recognise that the practical adoption of new technologies and cost effectiveness in community rehabilitation services are also issues for consideration (see for example Hilton et al, 2011). However, if effective in wider use, the device could produce gains in mobility, with less intensive clinical intervention, and could mitigate the impact of a growing, ageing population on health and social care services by enabling people after stroke to continue to function in the community for longer. Further benefits from improving mobility include delaying the onset of frailty, and resultant isolation, in addition to reducing health care costs of preventable problems such as falls and contractures, which are reported in over half of stroke survivors (NICE 2022).

Conclusion and recommendations

Haptic Bracelets provide an innovative development for use in rhythmic cueing in Stroke Rehabilitation. The results of this small-scale study add to the body of evidence supporting the use of a Haptic device such as the Haptic Bracelet as an adjunct to the post rehabilitation phase of stroke survivors. While there were positive responses to the Haptic Bracelets from participants, the findings indicate that more work is required to explore the; feasibility of using the Bracelets in community rehabilitation settings,

Future research and use of the Haptic Bracelets in practice should therefore focus on wider scale testing, the use of the Haptic Bracelets by participants in their own homes, design needs to improve the look size and ease of application and the cost benefits of using Haptic Bracelets as part of an overall program of stoke rehabilitation.

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Table 1 participant's demographics

Participant	Name/ hemiparetic side	Age	Time of stroke
1	(DP) Right	53 F	10 yrs.
2	(LH) Right Uses a walking stick	57 F	3 yrs.
3	(AS) Left Wears AF0	73 M	3 yrs.
4	(KR) Right Foot drop wears AFO	68 M	7 yrs.
5	(JR) Right hemiplegia Wears AF0	62 M	5 yrs.
6	(CH) Right hemiparesis	55 F	5 yrs.
7	(DK) RT	47 M	CP since birth Hemiparesis

Mean age of the participants 59.28 (±8.99).
(±8.65)
Mean time since stroke 11.42 (±15.87)

Key
AFO = Ankle Foot Orthosis
CP = Cerebral Palsy

Table 2 Stroke Survivors Priorities for the Development of a Haptic Cueing Device

- It has to work well so that users feel confident in its ability
- Must be able to put on and take off with one hand. Velcro was suggested a number of times. One handed pulling over to adjust tightness
- Needs to be lightweight –small enough to wear under trousers and make of a fabric that is comfortable to wear, even in hot weather
- The device should be made in skin colours (or ability to choose strap colour and change the strap)
- Ability to turn it off so it wasn't 'beating' while someone was sitting (e.g. in a restaurant). Ideally it would notice when you have stopped and work automatically according to the speed you are walking
- An information sheet (with pictures and simple language) and telephone helpline number to ensure patients are confident with its use
- Long battery life
- Silent
- Wearing it just above the knee was the preference because that is where it would be the easiest for patients to put on and take off without help from others. Both groups also raised the issue of the device looking like a 'tag' if it was worn around the ankle
- Speed variation (so when 'good leg' walks faster or slower the vibration
- keeps real time pace with that)
- Make it look more like a fitness accessory – stylish rather than a medical device
- Ability for patients to make any adjustments
- In both groups there was a minority voice that said that it didn't really matter what it looked like as long as it helped with walking, then participants would wear it.

Picture 1

Image reproduced from Georgiou (2018) with permission