A qualitative study exploring views and experiences of people with stroke undergoing transcranial direct current stimulation and robot arm therapy

Abstract

Background: Neurorehabilitation technologies used mainly in research such as robot therapy (RT) and transcranial direct current stimulation (tDCS) can promote upper limb motor recovery after stroke. Understanding the feasibility and efficacy of stroke rehabilitation technologies for upper limb impairments is crucial for effective implementation in practice. Small studies have explored views of RT by people with stroke; however experiences of people receiving tDCS in combination with RT have never been explored.

Objective: To explore views and experiences of people with sub-acute and chronic stroke that had previously taken part in a randomised controlled trial involving tDCS and RT for their impaired upper limb.

Methods: An interview study including a mixed method approach of open and closed questions. Face-to-face interviews were audio recorded. Open-ended question responses were transcribed and analyzed using thematic analysis; closed questions were analyzed using descriptive analysis.

Results: Participants felt that RT was enjoyable (90%) and beneficial for their affected arm (100%). From the open question data, it was found that the intervention was effective for the impaired arm especially in the sub-acute stage. Main reported concerns were that tDCS caused painful, itching and burning sensations and RT was sometimes tiring and difficult. Participants recommended that future research should focus on designing a more comfortable method of tDCS and develop a robot that promotes hand movements.

Conclusions: This study provides new knowledge about the benefits and barriers associated with these technologies are crucial to the future effective implementation of these tools in practice.

Keywords: non-invasive brain stimulation, robot, rehabilitation technology, upper limb, stroke, views

Introduction

Physical challenges such as motor deficits in the upper limb (UL) are a major cause of disability after stroke.[1] At six months' post-stroke, UL impairments persist in 30% to 66% of survivors.[2,3] Only 41% of people with moderate to severe stroke and 71% with mild stroke, regain dexterity.[4] Consequently, UL deficits have been associated with lower perceived health-related quality of life and higher levels of anxiety.[5,6]

One promising new approach for treating UL deficits after stroke is robotic therapy (RT) since it can easily deliver the key factors known to be important in promoting recovery such as repetition, intensity, goal orientation and feedback [7,8]. Quantitative evidence indicates that RT can lead to a small significant effect on UL motor impairments and strength compared to conventional therapy[9,10]. However, no effect on activities of daily living in stroke was observed.[8] The American Heart Association/American Stroke Association's Guidelines for Adult Stroke rehabilitation and Recovery recommend rehabilitation technologies such as Robot Therapy (RT) to provide some benefit for upper extremity motor abilities.[11]

In order to increase its effectiveness, RT has also been combined with non-invasive methods of brain stimulation such as transcranial Direct Current Stimulation (tDCS).[12,13] tDCS involves the application of direct currents transcranially via saline-soaked electrodes. Anodal tDCS increases cortical excitability whilst cathodal tDCS decreases it.[14,15] As a result, polarity-dependent changes in the motor cortex, can have a significant positive effect on UL motor function.[16] However, there is conflicting evidence on the effect of tDCS on UL impairments in stroke. Two studies reported significant positive effects of anodal tDCS in addition with rehabilitation programs on UL motor function[17,18] while another two studies did not report any significant differences.[13,19]

It is important to assess the practicality and acceptability of new technologies by combining qualitative as well as quantitative methods.[20] Although tDCS research has soared in the past 15 years, in-depth knowledge about the patient experience of tDCS with a stroke population is unclear since most studies on tDCS in stroke have only been reported as quantitative data.[14] Views about an intervention are often not captured from clinical outcome measures and questionnaires.[21] In contrast to tDCS, views and experiences of RT from people with stroke have been explored in three studies.[22,23,24] A small sample size of five participants with chronic stroke agreed that UL three-dimensional RT was usable and that their arm felt stronger but not functionally improved.[23,24] Using observation and semi-structured interviews, ten participants with sub-acute and chronic stroke reported a home-based RT system was beneficial for their UL mobility, a positive outlet for releasing anxiety and increased their independence in activities of daily living and motivation.[22] Barriers of use included technical difficulties and challenges when wearing and adjusting the device. The robot involved in this study promoted two-dimensional wrist movements but not functional shoulder, elbow and hand movements.

Due to the increase in popularity of three-dimensional UL RT and tDCS in stroke research, a concrete understanding about their feasibility RT for people with sub-acute and chronic stroke is needed. Therefore, a mixed-method approach embedded within a feasibility and pilot randomised controlled trial (RCT) involving tDCS and RT intervention for the impaired UL following a stroke, was conducted.[25] This paper presents the interview study using quantitative and qualitative methods to address the main aim, which was to explore views, concerns and expectations of new technology, tDCS, and RT for the impaired UL from people with sub-acute and chronic stroke who took part in the trial.

Methods

Design

A structured and semi-structured interview study (involving qualitative and quantitative components) was conducted. Closed questions with a Likert rating scale allowed the interviewer to follow a pre-determined schedule of questions. The interviews also involved open questions as used in previous research involving an identical RT for the impaired UL in stroke.[23] This allowed participants with the opportunity to express their views, concerns, expectations and perceptions.[26] Triangulation is the combination of two data sources.[27] Therefore, to strengthen the validity of findings triangulation between quantitative (closed question data) and qualitative (open question data) findings was used.[28] This study conforms to the COREQ Guidelines (Appendix Table A).

Recruitment and sample

Ethical approval to carry out this study was obtained from the UK National Research Ethics Service Committee South Central - Hampshire B (11/SC/0345). Participants were recruited from seven United Kingdom National Health Service sites and a private neurology clinic. All 22 participants who took part and completed the RCT, agreed to be interviewed and provided written informed consent. No further participants were selected. Participants fulfilled the following criteria: were ≥18 years, had a first confirmed clinical diagnosis of stroke by a neurologist, were >2 weeks post-stroke, with associated upper, forearm and hand paresis (Medical Research Council scale for muscle strength scores 2,3 or 4)[29] with minimal spasticity (Modified Ashworth scale ≤ 2),[30] had partial shoulder flexion against gravity, adequate sitting balance and the ability to provide informed consent. Participants were excluded if they had impaired gross cognitive function (<24 on the Mini-Mental State Examination),[31] any another neurological condition apart from stroke, shoulder pain resulting from shoulder flexion beyond 90º, epilepsy, implants in the brain, previous brain surgery, metal implants in the skull or brain including cochlear implants, medications that influence cortical excitability, or previous adverse effects when stimulated with tDCS and pregnancy.

Data Collection Procedure

For the intervention in the RCT, recruited participants were randomly allocated to two groups: (1) 20 minutes of real tDCS or (2) 30 seconds of sham tDCS, with both groups receiving 18 one-hour RT sessions. When the intervention was completed, an independent female interviewer (KM) with a Psychology background and a researcher at the time, who was not involved in the recruitment and data collection process and was also blinded to the participants' group allocation, conducted the interviews. These were conducted after the post-intervention assessment in the research laboratory or at the participants' home. The interviewer used an interview schedule which included topics focused on taking part in the trial, the effect of the intervention on arm movements and views, concerns and expectations in relation to tDCS and RT (Table 1). A digital audio recorder was used to record the interviews and field notes were taken during the interview, which lasted between 25 and 40 minutes. A pilot interview with the first participant with a sub-acute stroke was used to test and revise the interview schedule. The main revisions ensured that balanced positive and negative items were used in the interview guide.

[Table 1 about here]

Data Analysis

The data from the Likert responses from the closed questions of 21 participants (excluding the pilot interview) were entered into Microsoft Excel 2010 and percentages were calculated.

For the responses to the open questions, the audio recordings were transcribed verbatim. Data that compromised participants' anonymity or identified specific healthcare services were deleted from the transcript. Qualitative data analysis was conducted by the lead author and co-author of this paper (Physiotherapist (LTT) and Health Psychologist with an expertise in qualitative research (MDH)). The Physiotherapist knew the participants from the RCT, therefore, involving an external researcher to the project minimized risk of bias. The transcripts were numbered and then analyzed using thematic analysis, which involved reading and re-reading the transcripts and generating initial codes, identifying and reviewing key themes by the Physiotherapist. [32] These themes were collated in summary tables and for each theme the participants' views were summarized. For the purposes of data verification, the ranges of interpretations were reviewed and agreed upon by the Health Psychologist. Both researchers discussed the emerging themes and reached agreement concerning whether modifications should be made or if any themes should be split, combined or withdrawn. The final process involved defining and naming the final themes and selecting appropriate quotes to support each theme. It was confirmed that data saturation was reached in the analysis, as the themes remained stable after 12 interviews and no new themes emerged in the final transcripts.[33] Triangulation involving merged data integration for accordance and discordance between quantitative and qualitative results was then carried out. [34]

Results

Twenty-one participants (11 sub-acute and 10 chronic) with stroke with mean age of 64.2 (SD: 12.2) were interviewed (Table 2). The participants were experiencing mild (19%), moderate (48%) and severe (33%) upper limb impairments at the end of the trial.

Data integration showed that results were complementary about the positive effect of the intervention on their UL impairments and daily activities, the lack of improvement on hand movements and two-handed activities and the lack of comfort of the tDCS application using adhesive bandages. With regard to tDCS sensations, quantitative and qualitative data were discordant.

[Table 2 about here]

Closed question results

All the participants felt that they would recommend the intervention programme to other people with stroke, demonstrating its feasibility. After the trial, 86% of the participants reported feeling more aware of their impaired UL and that it felt stronger. The majority of participants (81%) reported feeling reduced tightness and 66% reported they could reach out easier with their affected UL after the intervention. Only 57% strongly agreed or agreed that they regained dexterity and could pick up objects (Figure 1).

[Figure 1 about here]

With respect to tDCS, the majority of the participants also reported that the electrodes were comfortable (95%) and that the stimulation was comfortable (81%). Mixed views were expressed regarding the adhesive head bandage used to hold the electrodes of the tDCS, with only 62% strongly agreeing or agreeing that it was comfortable (Figure 2). Regarding RT, 90% found the intervention enjoyable and 100% felt that the chosen games were beneficial for their affected arm (Figure 3). The participants also strongly agreed or agreed (95%) that they understood what they had to do (95%) and the target was clear whilst playing the games during RT (86%).

[Figures 2 and 3 about here]

Qualitative Results

The results are presented based on the following four themes: (i) effect of real tDCS and RT versus sham tDCS and RT intervention for the impaired UL (ii and iii) benefits and concerns regarding both technologies for people with stroke and (iv) recommendations on improving and developing both RT and tDCS applications. Supporting quotes for each theme are presented in Table 3.

Effect of real versus sham tDCS and RT intervention for the impaired UL

Regardless of receiving sham or real stimulation, most participants did not report feeling a difference in their performance immediately after the brain stimulation. In fact, one of the participants receiving real stimulation stated that probably the therapy was contributing to the improvements, rather than the brain stimulation specifically. On the other hand, one participant receiving real stimulation felt that he performed better during the games when the tDCS was switched on. Participants receiving sham stimulation did not experience any problems. However, one participant receiving sham stimulation expressed that she "expected" to feel more sensations to experience an effect from the intervention.

[Table 3 about here]

Benefits from RT

Participants reported that following every session, they felt that the intervention resulted in improvement in their daily tasks at home outside of the treatment sessions, such as opening doors, gardening, dressing, and that these positively affected their quality of life and increased their confidence. After the trial, all participants stated that if they had the opportunity they would continue RT. The participants felt that the RT was "fun", "amusing" and "interesting", "it helps in achieving something". Some also discussed how they thought that it brought out their competitive streak within their characters. Thee participants also expressed that they enjoyed the external support provided by the RT which removed the burden of the heavy weight of their affected UL.

Although participants discussed the "*big commitment*" of the intervention program, it appeared to give them a focus as they also wanted to improve their upper limb impairments. Participants with sub-acute stroke felt that the intervention was available at the "*right time*" of their stroke recovery. They expressed frustration about not going to work and feelings of being "*kind of cast adrift*". The participants felt that the research gave them confidence that "*someone*" was "*doing something*" for their stroke and that they had "*a reason to get up each day"*.

Participants with chronic stroke stated that it would have been more beneficial had they received the intervention earlier in their recovery process. In some cases, participants felt the research reminded them that they still have to deal with their impairment.

Concerns regarding tDCS and RT interventions

Participants expressed that they were skeptical before the trial and had some feelings of "fear" about the tDCS. Participants were concerned about the "electricity" that was applied via the electrodes and they were unsure whether there would be any consequences from the intervention. Although closed question data showed that the participants felt the stimulation was comfortable, those receiving real stimulation did report "light flashes", and sometimes the sensations were "itchy", "burning" and also "painful". They also added that since they were focusing on the RT during the stimulation, these sensations were minimized. Participants felt that wearing the electrodes made them feel "odd-looking".

Although finding RT enjoyable, participants expressed that they sometimes found it “tiring”, “frustrating” and “difficult”. These feelings were mainly due to the level of resistance of the spring mechanism of the robot, the computer graphics of the video games and severity of their UL impairments. The participants expressed that they felt that the computer graphics of the games during RT were not accurate, nor well designed resulting in feelings of confusion. Participants with severe UL impairments felt they would have liked to regain more movement from RT. They did not feel that they carried out two-handed tasks easier after the trial along the lines of washing the floor. Participants stated that despite being able to grip an object using two hands, they had difficulties with the release of the unilateral hand grip.

Recommendations on improving RT and tDCS applications

The participants had ideas about how the technology could be improved and integrated in future stroke research and clinical practice. With regard to RT, all the participants stated if they had another opportunity they would take part in RT again, but had certain reservations about the tDCS. It was suggested that for tDCS, a “less cumbersome” application such as cap or a “head band system” should be developed to hold the electrodes in place rather than using adhesive bandages. It was suggested that RT should be more patient-centered in the decision-making process such as setting the parameters and choosing the games. In addition, the visual feedback of performance should be clearer and easier to interpret. Participants with severe hand impairments felt that the RT should focus more on hand movement and extension of fingers, because this was their main limitation whilst carrying out activities. Home rehabilitation involving smaller “*cheaper version*” robotic systems was also was discussed by the participants. One participant was so motivated to practice, that he wanted a device at home. He stated the benefits as being the affordability and the convenience - avoiding problems with travelling to take part in research rehabilitation programs.

Discussion

The main findings from this interview study were that participants felt that the intervention was effective for improving their awareness, strength and reduction of tightness in their affected UL. However, mixed views were expressed about the effectiveness of the intervention on hand movements and the ability to pick up objects. The main benefit of the intervention was the enjoyable aspect of RT and the main concerns were that tDCS felt uncomfortable well as fatigue from RT. All participants provided recommendations for future research on how technology could be refined emphasising the need for hand rehabilitation.

To our knowledge, this is the first study that explored the views about tDCS in combination with RT from people with stroke. After the trial, it was determined that tDCS was acceptable to the participants, however from the qualitative data they had some reservations about its level of comfort. Participants stated that they experienced itching, burning and painful sensations. Itching is commonly reported in quantitative studies, however, burning and pain are rarely reported.[14] In order to prevent such sensations, an impedance monitor during tDCS application could be used in future trials. Due to the discomfort from tDCS and also the lack of evidence for its effectiveness, it is still early for tDCS to be integrated into stroke rehabilitation.[13,24] Participants expressed positive and stronger views about RT compared with tDCS, which could be due to tDCS paired with a more exciting intervention technique.

One of the main concerns of the participants was that the intervention did not improve their hand movements. The robot chosen for the present research trains hand grip rather than hand movements, so improvements in this domain would not be necessarily expected. UL and elbow robots have been shown to significantly improve global UL movements, however, there is a lack of research exploring the effect of hand robots in stroke.[8] This was also found in our study especially from participants with severe impairments and in similar research.[23] That leaves us with the continuous challenge faced by clinicians which is the lack of evidence-based therapy for poor recoverees.[35] Future research should address the possibility of developing hand robots with virtual reality which could potentially target severe impairments.

Stroke survivors undergoing rehabilitation programs have expressed negative experiences as they suggested that they should contain variety and stir feelings of enjoyment.[36] In the present study, apart from feelings of fatigue and frustration, overall positive experiences from RT were reported and are in line with similar research.[21,23] Participants were so motivated that they wanted to engage in the decision making for their RT program. However, qualitative research involving positive experiences about RT maybe not be seen as enough evidence for commissioners to fund the equipment. Additionally, in the present study, one of the concerns about RT was the lack of visual clarity of the some to the video games for people with stroke. Limitations in usability and clarity of new technologies have also been reported in similar research.[21, 37] Further research needs to explore the usability of such games in stroke rehabilitation.

Our research has a number of strengths and limitations. A particular strength is that the findings provided views of two types of rehabilitation technologies on health-related issues such as UL impairments in stroke. However, this work has some limitations. The interview schedule followed a structured process which could have impacted the depth of the qualitative analysis. Participants were not able to determine whether or not they had real or sham therapy which could have impacted their views of tDCS. The participants in the real group were more severely impaired in the UL which could have influenced the effect of real versus sham tDCS. The first author of this paper was the lead person who developed the protocol, recruited, performed quantitative data collection for the RCT, and analyzed the qualitative data. Having spent considerable time with the participants this could have instigated some bias in the qualitative data analysis. To minimize this, the researcher who conducted the interviews and assisted in the data analysis and presentation for the present study was not a health care professional and not involved in the main RCT.

Future stroke research should address a more comfortable method of tDCS application with standard rehabilitation programs. Additionally, develop and test robots that incorporate and promote hand movements incorporating the game graphics to be more suitable to people with stroke. These interventions could provide the opportunity for much longer-term and effective rehabilitation for people with stroke.

Conclusion

The present has provided a greater understanding about the effect of combining real or sham tDCS with RT for people with sub-acute and chronic stroke. The intervention, especially RT, was effective and beneficial for UL impairments and activities in stroke. However, tDCS was not comfortable for some participants and the RT games require further development. Future stroke research should seek more comfortable methods of tDCS application and develop a RT therapy for hand rehabilitation.

Declaration of Interest

None to declare.

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Tables

Table 1: Interview schedule containing a mixture of open and structured questions

1) Effect of intervention on arm movements
Open questions Did you feel any differences about your everyday life during or after the trial? (open) Did you feel any differences in your activities immediately after brain stimulation? (open)* *Structured Questions* a) I am now more aware of my affected arm (Likert Scale: Strongly agree, agree, neutral, disagree, strongly disagree b) After the research study, my arm feels weaker (Strongly agree, agree, neutral, disagree, strongly disagree) c) My arm feels less tighter (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) d) I can reach out with my arm more easily (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) e) I can now pick up objects (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) *Open questions* f) Are you now able to do things that you could not do before? g) Are you now able to do things better than you could before? h) Can you now perform any two handed tasks more easily?
2) Views on RT and tDCS
Closed questions ***Robot*** a) I did not find the treatment enjoyable (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) b) It was easy to understand what I had to do (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) c) The target during the robot assessments and games was easy to see (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) d) The games chosen were beneficial for my weak arm (Strongly agree, agree, neutral, disagree, strongly disagree) e) I understood the graphs showing my performance (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) ***Brain Stimulation**** a) The stimulation was comfortable (Likert) (Strongly agree, agree, neutral, disagree, strongly disagree) b) The pads placed on my head were comfortable (Strongly agree, agree, neutral, disagree, strongly disagree) c) The bandage placed around the electrodes was comfortable (Strongly agree, agree, neutral, disagree, strongly disagree) *Open questions* How do you think the non-invasive brain equipment could be improved? What were the best and worst aspects of the non-invasive brain stimulation? What were the best and worst aspects of the robot therapy? How robot therapy and non-invasive brain stimulation could be improved?

Table 2: Participant characteristics

Participant Number	Gender (M/F)[1]	Age (years)	Sub-acute/ Chronic Stroke[2]	Level of upper limb impairment at the end of the trial[3]
Sham Group				
1	M	71	Sub-acute	Mild
2	F	60	Sub-acute	Mild
3	M	78	Sub-acute	Mild
4	F	83	Sub-acute	Moderate
5	F	76	Sub-acute	Moderate
6	M	53	Chronic	Severe
7	M	49	Chronic	Moderate
8	M	58	Chronic	Severe
9	M	37	Chronic	Moderate
10	F	71	Chronic	Severe
Real Group				
11	F	79	Sub-acute	Moderate
12	M	72	Sub-acute	Severe
13	M	68	Sub-acute	Moderate
14	F	47	Sub-acute	Mild
15	F	57	Sub-acute	Severe
16	M	63	Sub-acute	Moderate
17	M	68	Chronic	Severe
18	F	48	Chronic	Moderate
19	M	65	Chronic	Moderate
20	M	71	Chronic	Severe
21	F	74	Chronic	Moderate

[1] M= Male; F=Female
[2] Sub-acute=2 weeks to <4 months post-stroke; Chronic=<4 months post-stroke
[3] Based on Fugl Meyer Assessment of upper limb motor impairments; mild= score 0-27, moderate= score 28-57, severe= score 58-66 (Pang et al., 2006)

Table 3: Themes and supporting quotes

Theme	Participants' Quotes
Effect of real versus sham tDCS and RT intervention for the impaired UL	*"I thought to myself I did better with it switched on because I could feel when it was on I could feel the switch go on and off and I could also feel just a wee bit of warmth from the pads so I sort of knew when it was on and a couple of times I thought to myself I did better with it on than I did with it off"P16*
	"I like to think that something stronger was being used you know what I mean it was actually, I expected to feel more than I did…"P5
Benefits from tDCS and RT interventions	RT: "*Best aspect it gives you freedom to move your arm, worst aspect you have got to stop doing it and go home, so your arm goes back to you know a lot to what it was except that I could move it a bit it still went back to being heavy, it is the lightness it gives you…"P15*
	RT: *"The best playing the game getting 100% and doing it quicker than the previous time…I mean the researcher would say oh you did that in 3 seconds quicker or you got 100%...and last time you only got and then she would put the graph up"P16*
	RT and tDCS: *"Only that it gave me the confidence of moving forward...gave me confidence that something was being done you know rather than being left to pull yourself together"P14*
Concerns regarding tDCS and RT interventions	tDCS: *"The worst bit, I think not knowing what that thing is doing to you brain, when they are shooting them into your head you don't know… whether it was doing negatives you are looking for positives"P19*
	tDCS: *"stimulation normally produced a sensation that one can recognize, pleasurable or otherwise, well I other than a sort of slight itchy burning to start with when a current was apparently switched on my brain..."P17*
	RT and tDCS: *"I did mop the floor and I did have to try and hold the other end of the mop with the left hand so I had a go but it wasn't very successful"P6*
Recommendations on improving RT and tDCS applications	"*I would like to think I would get some movement in my fingers so anything that helps my fingers in particular would be great but any, any part of the body I suppose would be good but fingers specifically…"P7*
	"my partner is going to try and build me a robotic arm…she is going to do me a wooden one with pulleys and hinges so that I can just practice moving it around…because I don't want to stop everything just because I have stopped here, there is no point otherwise" P16

Figure Captions

Figure 1. Percentage responses of closed questions about the effectiveness of the intervention program (N=21)

Figure 2. Percentage responses of closed questions about the experiences of tDCS (N=21)

Figure 3. Percentage responses of closed questions about the experiences of RT (N=21)