

Participant perceptions of use of CyWee Z as adjunct to rehabilitation of upper-limb function following stroke

Leigh A. Hale, PhD;^{1*} Jessica A. Satherley, BPhy;¹ Nicole J. McMillan, BPhy;¹ Stephan Milosavljevic, PhD;¹ Juha M. Hijmans, PhD;² Marcus J. King, BE³

¹The REAL Neurology Research Group, Centre for Physiotherapy Research, University of Otago, Dunedin, New Zealand; ²Department of Rehabilitation Medicine, Centre for Rehabilitation, University Medical Centre Groningen, University of Groningen, Groningen, the Netherlands; ³Industrial Research Ltd, Christchurch, New Zealand

Abstract—This article reports on the perceptions of 14 adults with chronic stroke who participated in a pilot study to determine the utility, acceptability, and potential efficacy of using an adapted CyWee Z handheld game controller to play a variety of computer games aimed at improving upper-limb function. Four qualitative in-depth interviews and two focus groups explored participant perceptions. Data were thematically analyzed with the general inductive approach. Participants enjoyed playing the computer games with the technology. The perceived benefits included improved upper-limb function, concentration, and balance; however, six participants reported shoulder and/or arm pain or discomfort, which presented while they were engaged in play but appeared to ease during rest. Participants suggested changes to the games and provided opinions on the use of computer games in rehabilitation. Using an adapted CyWee Z controller and computer games in upper-limb rehabilitation for people with chronic stroke is an acceptable and potentially beneficial adjunct to rehabilitation. The development of shoulder pain was a negative side effect for some participants and requires further investigation.

Key words: balance, computer games, concentration, CyWee Z controller, function, general inductive approach, qualitative, rehabilitation, stroke, upper limb.

INTRODUCTION

Stroke is the third leading cause of death in New Zealand and a major cause of adult disability for those who

experience it [1]. Approximately 85 percent of patients with stroke do not regain upper-limb function and remain dependent on caregivers [2–3], with motor impairments accounting for most poststroke disability [4]. Loss of upper-limb function is a major cause of poor perception of well-being following stroke [5].

Most recovery of upper-limb function occurs in the first 3 months following a stroke; however, significant gains in dexterity, strength, and function with rehabilitation 6 months poststroke have been reported [6–7]. This subacute recovery in motor function can be explained in part by neural reorganization caused by rehabilitation training [8–12]. It is suggested that key factors to upper-limb stroke rehabilitation training are attention, repetition, intensity of practice, reward, progression of complexity, and skill acquisition and that this training should be task-oriented [12–13].

Computer-assisted technology, such as virtual reality, is considered a useful addition to rehabilitation because it offers a potential medium by which these key aspects can be provided [13–15]. In virtual reality, the user experiences a simulated “real” environment using dedicated

*Address all correspondence to Leigh A. Hale, PhD; University of Otago, School of Physiotherapy, PO Box 56, Dunedin, 9054, New Zealand; 64-3-479-5425; fax: 64-3-479-8414. Email: leigh.hale@otago.ac.nz

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computer software [14–15]. Virtual reality ranges from immersive to nonimmersive paradigms. Immersive virtual reality provides the user with the perception of immersion in a real, three-dimensional environment [14–15]. With nonimmersive virtual reality, the user interacts with a computer screen with an interface device and therefore has a reduced feeling of immersion [14–15]. Less immersive environments commonly use a desktop computer monitor, are easy and convenient to use, allow both the therapist and the patient to view the same scene, and are less expensive than immersive virtual reality [14].

Virtual reality potentially provides a stimulating experience, engages and motivates the user, and allows the practice of motor movements as the user manipulates the interface device [15]. Studies have reported increased participant motivation, enjoyment, or perceived improvement in physical ability after including virtual reality into stroke rehabilitation [16–19], although to date, the evidence of improvement for these factors is not strong [20]. An important element to investigating novel interventions is to explore the users' perceptions [21].

The interaction between the user and the virtual environment can be achieved through a variety of commercially available interface devices [14–15]. We have adapted a low-cost interface device, the CyWee Z handheld game controller (CyWee Group Ltd; Taipei, Taiwan) [22], to provide a nonimmersive virtual environment for computer gaming for upper-limb stroke rehabilitation. The system allows the user to exercise his or her affected upper limb with support and assistance from the nonaffected upper limb in a bilateral manner. We conducted a pilot study to determine the utility, acceptability, and potential efficacy of using the CyWee Z controller and computer games in upper-limb rehabilitation for people with chronic stroke [23]. Because an important part of developing new interventions is end-user feedback [21], this article reports on the perceptions of participants who took part in this pilot study of the use of the adapted CyWee Z controller and of computer gaming in general as rehabilitation tools.

METHODS

Design and Recruitment

This qualitative study used an evaluative paradigm [24]; we used in-depth interviews and focus groups to explore the perceptions of participant experiences using

the adapted CyWee Z controller with a range of computer games as a technique to enhance upper-limb function following stroke. The pilot study used a control-wash-out-intervention design [23]. As part of the control phase of the study, participants played computer games with their nonaffected hands using a mouse interface four times a week for 2.5 weeks. There was then a 2.5 week break, during which no intervention was provided. Then, as part of the experimental phase, participants played computer games using an adapted CyWee Z controller, modified to be held with both hands with a specially designed plastic tube (called the “wand”), four times a week for 2.5 weeks [23]. The affected hand was bandaged to the wand if the participant was unable to hold onto the wand effectively with this hand. The goal of this intervention was to encourage repetitive movements of the affected upper limb; the bilateral nature of the intervention allowed for either active or active-assisted movement of the affected upper limb. Therapists supervised all game play sessions, guided selection of appropriate levels of games, or advised correct use of the adapted CyWee Z controller and subjectively assessed for any adverse reactions before and after each session.

Game Design

A suite of computer games provided a graduated series of challenges. In the first games that participants played, several targets (cartoon animals or music notes) moved around the screen and the participant had to move the cursor over the target in order to capture them (*Mosquito Swat*, *Music Catch*, and *ReBounce*). In subsequent games, the participant had to select a target to click and move according to a simple strategy (*Bejewelled* and *Balloon Popping*). A range of further games, such as simple sports-based games (*10-Pin Bowling* and *Air Hockey*), creative games (*Paint By Numbers*), and classic puzzle games (*Mah-Jong* and *Solitaire*), were also available to play. All games required large cursor movements in both the horizontal and vertical directions. The games were played for 45 to 60 min during 8 to 10 sessions over a period of 2.5 weeks. In the first two sessions, we presented the simple moving-target hitting games; after that, the participants could choose which game to play: either a new or a known game. The cognitive requirements to play the games were low, with large, easy-to-see objects and icons, basic sports concepts, or simple puzzles.

Device

The CyWee Z controller is a movement-based handheld game controller [22] similar to the Nintendo Wii controller. We incorporated the device into a handlebar between 350 and 500 mm long. The length of bar chosen

for use depended on individual participant choice and body size. Rotations of the device in the transverse plane produced horizontal mouse cursor translations on the screen, while rotations in the sagittal plane produced vertical mouse cursor translations (**Figure**).



Figure.

Movements required for controlling cursor on computer screen using CyWee Z controller (CyWee Group Ltd; Taipei, Taiwan) incorporated into handlebar. *Source:* Hijmans JM, Hale LA, Satherley JA, McMillan NJ, King MJ. Bilateral upper-limb rehabilitation after stroke using a movement-based game controller. *J Rehabil Res Dev.* 2011;48(8):1005–14.

Participants

We recruited 22 participants from the local stroke club and using public media advertisements. We asked people interested in participating in the study to contact the researchers. We then explained the study in detail and provided information sheets. After obtaining verbal consent, we screened each volunteer for inclusion and exclusion criteria. To be included in the study, volunteers had to be ≥ 18 years old with a definite diagnosis of stroke that occurred ≥ 6 months prior; have some voluntary movement in their arm affected by stroke (defined as achieving a score of 4 out of 6 on the upper-arm function score of the Motor Assessment Scale [25]); be presently of good health; have no self-reported orthopedic, medical, or painful conditions that would prevent them from using the CyWee Z controller comfortably; and be able to provide written informed consent. We excluded volunteers if they had fixed contractures in the affected upper limb preventing use of the CyWee Z controller and/or an inability to understand the project and its requirements (e.g., because of dementia or receptive aphasia).

Of the 22 volunteers, 16 were eligible and consented to participate. Consent included participation in both the quantitative and qualitative components of the study at the completion of the experimental phase. One participant dropped out prior to study commencement and another participant prior to commencement of the intervention stage, both because of family commitments. All 14 participants who completed the study participated in the qualitative component. We obtained information regarding the participant's stroke directly from the participant. The quantitative study has previously been published [23].

Procedure

Upon completion of phase 2 of the study, we invited participants to participate in a focus group discussion. Four participants had difficulty speaking because of their stroke (these participants had dysarthria, resulting in them being quietly spoken or difficult to easily understand) and so agreed to participate in individual interviews with one researcher (L. H.). The remaining 10 participants attended one of two focus group discussions, attendance depending on which focus group best suited their schedule; six participated in one group and four in the other. The focus groups were led by one researcher (L. H.), but two other researchers (S. M. and M. K.) assisted with both groups.

Each individual interview or focus group explored participants' perceptions using open-ended questions. Because

this study was evaluative [23] in nature, the questions emphasized and explored issues of utility, feasibility, and propriety, namely, (1) what participants thought about playing with the adapted CyWee Z controller and computers in general, (2) whether they derived any benefit from using this technology, (3) how they felt this intervention contributed to stroke rehabilitation, (4) what things they would like to see improved in the technology, and (5) whether they thought it was something they would like to use at home without supervision. The interviews and focus groups were audio-recorded and lasted approximately 10 and 40 min, respectively. Each audio-recorded session was transcribed word-for-word.

We used the general inductive approach to analyze data because this approach answers specific study research questions by identifying the connections between the research objectives and the summary findings derived from the raw data [26]. In the analysis process, researchers systematically and meticulously read all transcripts, both from the individual interviews and the focus groups, and developed a coding framework after discussion. Upon further deliberation, the codes were collapsed into categories, which in turn were conceptualized into the main themes. Although participants did not have the opportunity to verify transcripts, we presented the results to the local stroke club and discussed comments made by attendants; this process was considered robust to assess the trustworthiness of data analysis [26].

RESULTS

The participants comprised five females and nine males, who averaged 71 ± 12 years old (mean \pm standard deviation; range: 47–85 yr). The stroke affected eight participants on their right side and six on their left side, and time since stroke ranged from 1 to 6 years. At baseline, the average Fugl-Meyer Assessment upper-limb score [27] was 44.7 ± 17.1 (range: 14–65).

Five main themes emerged from the data: enjoyment, benefits, shoulder pain, suggested changes, and use of computers in rehabilitation.

Enjoyment

The overriding opinion of all participants was that they enjoyed playing with the technology. One participant said, "I've never been a computer buff at all but...I enjoyed it quite well." When asked what they enjoyed about playing

with the technology, two participants talked about enjoying the challenge that it provided them: “I enjoyed the challenge of the different games...and getting on top of them...I’m making my hand work on all of them...It mostly made the brain think and that was good for me because it’s almost 6 years since I’ve had mine [stroke] and most things are working but aye this brain stimulus is the thing.” Another participant reiterated this point, saying, “I enjoyed working on the computer with the, um, physical side of having to compete with...the computer screen and set yourself a target today and coming back tomorrow and trying to beat your scores from yesterday sort of style.”

Benefits

All but one participant felt they had benefitted from playing with the computer technology. Perceived gains were in improved upper-limb use, balance, and concentration. When we queried the participant who felt his balance had improved regarding how this could occur after participating in a seated activity, he said that playing the games had increased his ability to concentrate, which made him focus better when he was walking in an environment that challenged his balance. A number of participants felt that being able to use both arms simultaneously with the wand while using the adapted CyWee Z controller was beneficial, because they did not often get the opportunity to use both hands at the same time. One participant reported improved ability to push her manual wheelchair. Prior to the intervention, she had problems pushing with both hands simultaneously and was thus unable to push the wheelchair straight. By the end of the intervention, she was able to push herself around the block in her neighborhood. In addition, she was able to eat with both a knife and a fork, instead of one-handed, and was able to assist more with dressing herself. This participant felt her concentration had also improved tremendously and she could focus for much longer periods. One participant felt that his hand movement had improved even though he knew his test results from the quantitative component of the study would not demonstrate this improvement: “It’s been, its quite beneficial for my hands and, ah, basically my hands, I couldn’t move them last week...even though in all the tests may not have shown the improvement, there has been improvement.” One participant said he could now hold the car steering wheel with both hands.

However, one participant did not feel he had made any gains, although he had enjoyed learning how to use

the computer. This participant developed pain in his shoulder every time he started to play with the adapted CyWee Z controller and felt, because of this, that he had not been able to make any gains.

Participants agreed that computer gaming technology should be included into stroke rehabilitation programs, although one participant felt that it should not be introduced too early and that it would be better commenced once some voluntary hand movement had returned. One participant considered that with reduced access to rehabilitation services, home-based and/or computer-based technology gave a person the opportunity to engage in rehabilitation on his or her own.

Shoulder Pain

Shoulder pain was a side effect of playing with the adapted CyWee Z controller. Six participants complained of either pain in the affected shoulder or an ache in the affected arm. Mostly the pain occurred after a little play and would ease over night.

Participant: “The arms are getting sore from here [shoulder] and the elbow.”

Researcher: “So it’s been painful before you started playing those games or because of playing the games?”

Participant: “Because of playing the games.”

One participant offered an explanation for this pain: “Made you move muscle that you don’t usually move, you know, when you have the controls. Ah, I got quite a lot of scapular pain, you know, that normally I don’t get but I’m sure it’s because you were using your shoulder more than you would normally.” For most participants, the pain was more of a “discomfort” that appeared while playing and might last into the evening but be gone by the next day.

Suggested Changes

Participants considered that the games offered were mostly good, but they preferred puzzle games that made them think (e.g., *Solitaire*) or the target-hitting games they could relate to (e.g., the “swatting the flies” game). Although scores achieved after playing a game did help the participant to try to beat the score the following game, the participants in the focus group did not think it was an essential part of game play. Participants liked the games to be challenging and create a little frustration so they felt they had to “make sure you got on top of it.”

During one focus group, two participants spoke of this frustration, with one participant saying, "Not the way she was growling some days when she couldn't get it to work," to which the other participant said, "Well if you're not that sort of competent with...computer it can be frustrating especially when the beastly things go flying around and you can't stabilize it." Participants did recognize that although the games that made them think, such as *Solitaire*, were good, games that actually made them use their arm more were better since the aim of play was to improve arm and hand movement.

Most participants said they preferred the wand of the adapted CyWee Z controller that allowed them to play bilaterally as opposed to using a mouse controller, although the wand could get heavy after a period of play and might have been too long, resulting in the hands being too far apart.

Participant: "Yeah, I think that one hand steadied it and you did it with the other one 'cause you had to use your controls on your affected hand but you were steadying it with the other one. If you were trying to use those controls and use the thing I don't think I could have managed. I could use the wand down here but ah to lift it up and ah use two fingers would have been a lot more difficult."

However, technical issues such as using the CyWee Z trigger switch embedded in the wand and mouse cursor drift were problematic for them.

Participant: "The trigger thing was alright for me, trying to find that wee button underneath was hard 'cause you could feel it up and down but if it was proud just a wee bit you could click it straight away and then it would be easier to stop everything and move over and start again. But I was away over here chasing things and ah whereas if I could find that and I wasn't the only one that ah missed it that way."

When we asked if a bigger screen would be beneficial, the general opinion was that this was not necessary and would add to the cost. Participants considered the colors used in the games to be appropriate, except for one game, which used a purple color that appeared to fade and thus was difficult to see. This game had a music component to it, and the focus group then discussed the use of music. The participants agreed that music can be helpful in trying to get movement going again, and one participant suggested creating a game in which the player had to

compose a piece of music. An additional technical complication was that presently the games were only Microsoft computer compatible, which was not suitable for all people for home use.

Use of Computers in Rehabilitation

We asked participants whether they thought they would use the computer games at home if they had the opportunity, and most participants were keen to do this. Participants stated that they felt regular exercise would be beneficial: "I think you need everyday twice a day but it is fun."

Three participants wanted to buy the CyWee Z controller and games for home use; others were going to buy a computer.

Participant: "Ah, I'll see what the, what the ah the chances of buying a computer will be."

Researcher: "You think you're that hooked!"

Participant: "Oh, not that hooked but it could be ah I ah better, I've got three nephews and they all have computers and my brother-in-law, they've got a computer too and ah I find it they're on them all the time."

One participant felt that one had to take what opportunities one could to improve, particularly in a climate of healthcare that did not provide much rehabilitation: "Rehabilitation is getting so difficult for people of our age. It's getting less and less available and if you have something like this that can become available um quite cheaply to people of ah I mean I don't consider myself old but after having a stroke I'm being told I was too old for rehabilitation. Um I walked along here and arranged my own ah but I had enough knowledge to do that a lot of people don't...But um, it's there are still very little rehabilitation for the over 70s, um, and if you can get something to help you then by all means push it."

One participant did not think that playing computer games would have been useful in the early stages after stroke because she would not have had enough movement in her hand to engage in it: "I do know that you wouldn't be able to start those games um in the [acute rehabilitation] center cause I couldn't have done anything. It would have to be done in rehab later on."

However, later into rehabilitation, one participant found that learning how to use a computer gave him back a life: "Well I'm 75 and ACC [Accident Compensation Corporation; comprehensive, no-fault personal injury coverage

for all New Zealanders] don't want to know us cause we're non-earnings you know you do something and they just cause ya on the pension and everything else they just don't want to know. But I couldn't use a computer before I had my stroke and ah one of the [occupational therapists] rang me from the from the Center, there goes the memory gone again, and um he sent, the hospital sent a guy out to show me how to use the computer and he spent an hour a week for a year. And after that I employed him for another year and ah we came mates so I see him once a week now but a third computer [laughs]. But I use them for entertainment. I'm not interested in sending emails or anything like that I've got to think too much, I'm not that good at my typing but I can get on the everything else. See my DVDs, movies, and everything else like that."

Participants were not sure if people attending the local stroke club would play the games if they were provided by the club: "Some of them would and some of them wouldn't." When we asked if this might be a generation issue, participants did not think so.

Participant: "I think so. I've got grandchildren, they all play computers."

Researcher: "So you can join in now?"

Participant: "Yes."

DISCUSSION

All participants in this study enjoyed using the adapted Cywee Z controller and the computer games, finding the intervention physically challenging and mentally stimulating. Similar findings have been reported in other small studies using a variety of virtual reality systems, both immersive and nonimmersive [16–17,28–29]. However, these studies, like the present one, only acquired participant feedback after a short laboratory-based protocol. One of the rationales for computer-based rehabilitation is the use of the motivational aspects of the technology to stimulate people to practice repetitive movement to facilitate neuroplasticity and enhance functional movement [15–17]. To date, no study has provided a virtual reality-based intervention over prolonged periods of time in a home-based setting for participants to use at their discretion (thereby exploring the premise that virtual-reality game play enhances motivation and thus practice), whereby, arguably, the novelty of playing may wane and use of the technology slowly diminish. Piron et al. have investigated a combination of virtual reality and telerehabilitation in the home

environment, but participants were restricted in this study to playing 1 hour a day, 5 days a week for 1 month [30]. Exploring the novelty factor in enhancing motivation to practice movement is a possible next step in investigating this type of intervention.

The basis of most of the enjoyment of using the technology in this study appeared to focus on the games rather than on the interface. This is not surprising, provided that the games are well designed. "Flow" is a term used to describe the almost trance-like state that occurs when a video game player is completely focused on playing the game, and everything else seems to fade away—a loss of awareness of one's self, one's surroundings, and time. When a player enters a state of flow, the computer interface no longer appears to be critical to the experience [31].

The intervention in this study targets upper-limb movement and function. However, although participants felt they had made upper-limb function gains, they also reported improved concentration and balance. The latter two attainments appear to be novel findings. When we explored this concept further with participants in the focus groups, one participant said he found that, postintervention, he was able to concentrate for longer than before. This participant considered his balance improved because he concentrated more and for longer when walking in the community. While a number of studies have reported upper-limb functional gains with virtual reality (both immersive and nonimmersive), none have mentioned improvement in concentration or balance when the intervention was aimed at improving upper-limb function. Although it is an idiosyncratic finding of this study, it maybe a concept worthy of further exploration.

Participants in this study enjoyed having a range of computer games to play, preferring the games that made them think and those that they could relate to; these findings are similar to those reported in other participant-feedback virtual reality studies [28–29]. Participants in the present study did acknowledge that some of the games that made them "think," such as the puzzles *Solitaire* and *Mah-jong*, did not provide much opportunity for the practice of arm movement, the stated goal of the intervention in this study.

Although participants said they liked to attempt to better their game play and obtain a higher score, interestingly, the level of the actual score itself did not seem to be an important feature to them. In comparison, Lewis et al. found that for some participants, challenging themselves during computer-based games and observing progress

through levels of difficulty and real-time score feedback meant encouragement to continue trying [32]. Some authors consider providing a score following the playing of a computer game important, because scores and similar feedback allow for performance feedback, which promotes learning [14,33].

Participants considered that being able to play the computer games using both arms in a bilateral movement fashion was a plus. Not only did this strategy assist their affected arm to move, but they also considered it more akin to normal movement. One participant, who drove himself to the sessions, commented on how he could now hold onto the steering wheel of the car with both hands. Another participant was now able to push her manual wheelchair with both hands, thus going straight. This finding was not surprising because bilateral therapy has proven efficacy in functional recovery of the upper limb following stroke [34–37].

Perhaps one of the most important findings from this study was the fact that some participants reported pain in the shoulder or an ache in the affected arm during and/or after play. For one participant, the pain prevented him from enjoying the sessions and he felt that the intervention had been of no benefit to him. This appears to be the first study reporting on the use of computer-based game playing as an intervention poststroke that has reported pain as a possible side effect. Although we did not specifically assess or diagnose the cause of the shoulder pain, one possible reason for the pain may be the sudden increased intensity and duration of unaccustomed movement of the affected arm. Furthermore, the type of movement produced in the affected arm by playing with the adapted CyWee Z controller may have caused pain. Niessen et al. advocate, based on a case-control study ($n = 21$ people with stroke, $n = 10$ nondisabled adults), that kinematics and proprioception of the affected shoulder can alter following a stroke, which may lead to secondary repetitive soft tissue pathology and chronic pain [38]. Fotiadis et al. highlighted the complexities of diagnosing the cause of shoulder pain poststroke, with many potential reasons implicated, including that of abnormal patterns of muscle activation [39]. The development of pain with this type of intervention requires further investigation, and interventions of this nature should be introduced with a gradual build of duration and intensity of play. The actual movements that occur in the arm during game play also need careful examination. Computer technologies have an associated risk of overuse injury, and although stroke

rehabilitation requires movement repetition, it is possible that safety systems should be considered to prevent overuse. Understanding the specifics of a particular game and the movement it potentially initiates in the user is important and should be part of the clinical decision-making incorporated into the use of such technology.

To aid such decision-making, Broeren et al. report that they are creating a taxonomy of neurological impairments, stroke rehabilitation exercises, and rehabilitation goals, which they anticipate could be associated with specific computer games so that an appropriate game can potentially be chosen to facilitate the desired outcome [40]. Similarly, Galvin and Levac have developed a classification system of virtual reality systems to aid clinical decision-making in pediatric rehabilitation [41].

CONCLUSIONS

Participants with chronic stroke enjoyed and reported perceived gains in upper-limb movement, concentration, and balance following 8 to 10 sessions of playing with the adapted CyWee Z controller and a range of computer games. The development of shoulder pain was a negative side effect for some participants and this requires further investigation, which should probably include a kinematic analysis of the upper-limb movements used during game play with this technology. Using the adapted CyWee Z controller and computer games in upper-limb rehabilitation for people with chronic stroke is an acceptable and potentially beneficial adjunct to rehabilitation.

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Author Contributions:

Study concept and design: L. A. Hale, J. M. Hijmans, M. J. King, S. Milosavljevic.

Acquisition, analysis, and interpretation of data: L. A. Hale, J. A. Satherley, N. J. McMillan.

Drafting of manuscript: L. A. Hale, J. A. Satherley, N. J. McMillan, S. Milosavljevic, J. M. Hijmans, M. J. King.

Critical revision of manuscript for important intellectual content: L. A. Hale, J. M. Hijmans, M. J. King, S. Milosavljevic.

Qualitative analysis: L. A. Hale, J. M. Hijmans, M. J. King, S. Milosavljevic.

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