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Contents

Original Papers

Review

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Viewpoint

XSL•FO
RenderX

Original Paper

Indigenous Adolescents' Perception of an eMental Health Program (SPARX): Exploratory Qualitative Assessment

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Abstract

Background: Depression is a major health issue for indigenous adolescents, yet there is little research conducted about the efficacy and development of psychological interventions for these populations. In New Zealand there is little known about taitamariki (Māori adolescent) opinions regarding the development and effectiveness of psychological interventions, let alone computerized cognitive behavioral therapy. SPARX (Smart, Positive, Active, Realistic, X-factor thoughts) is a computerized intervention developed in New Zealand to treat mild-to-moderate depression in young people. Users are engaged in a virtual 3D environment where they must complete missions to progress to the next level. In each level there are challenges and puzzles to completeIt was designed to appeal to all young people in New Zealand and incorporates several images and concepts that are specifically Māori.

Objective: The aim was to conduct an exploratory qualitative study of Māori adolescents' opinions about the SPARX program. This is a follow-up to an earlier study where taitamariki opinions were gathered to inform the design of a computerized cognitive behavior therapy program.

Methods: Taitamariki were interviewed using a semistructured interview once they had completed work with the SPARX resource. Six participants agreed to complete the interview; the interviews ranged from 10 to 30 minutes.

Results: Taitamariki participating in the interviews found SPARX to be helpful. The Māori designs from the SPARX game were appropriate and useful, and the ability to customize the SPARX characters with Māori designs was beneficial and appeared to enhance cultural identity. These helped young people to feel engaged with SPARX which, in turn, assisted with the acquisition of relaxation and cognitive restructuring skills. Overall, using SPARX led to improved mood and increased levels of hope for the participants. In some instances, SPARX was used by wider whānau (Māori word for family) members with reported beneficial effect.

Conclusions: Overall, this small group of Māori adolescents reported that cultural designs made it easier for them to engage with SPARX, which, in turn, led to an improvement in their mood and gave them hope. Further research is needed about how SPARX could be best used to support the families of these young people.

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KEYWORDS

Māori youth; indigenous; depression; computerized CBT; consumer views; serious games; virtual worlds

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Introduction

Global Understanding of Depression

Depression is a major contributor to poor health [1] and is a global concern, with lifetime prevalence rates of depression ranging from 15% to as high as 25% [2]. Depression is common among children and adolescents, with community studies showing reported rates of 4-7.5% in international adolescent populations [3,4]. Depression in adolescence can persist into adulthood and has a variety of adverse psychiatric and psychosocial consequences (eg, poor academic performance, social dysfunction and substance abuse) [5-11].

Māori Experience of Depression

In New Zealand (NZ) mental illness has long been identified as one of the most significant threats to the health status of all young people, with Māori an important indigenous group within the population [12,13]. A New Zealand–representative study showed that rates of depression for Māori high school students (at 13.9%) were comparable to young European New Zealanders (12.1%), with 18.3% of Māori girls and 8.7% of Māori boys reporting depressive symptoms in the clinical range on the Reynolds Adolescent Depression Scale-Short Form (RADS-SF) [14]. With low rates of access to mental health services reported for all groups (particularly for taitamariki) and with the rising numbers of young Māori in New Zealand [14], it is important that mental health resources are available to them.

Cognitive Behavioral Therapy

The National Institute for Clinical Excellence recommends cognitive behavioral therapy (CBT) as the preferred psychological therapy for treating mild to moderate depression in children and adolescents [15] with emerging evidence that computerized CBT (cCBT) can be as effective as treatment as usual in the reduction of depressive symptoms in adolescents [16,17,18,19] and superior to waitlist control [20].

Cognitive Behavioral Therapy and Māori

CBT in relation to ethnic minority groups has been criticized because of its perceived lack of relevance to some of these groups [21]. CBT foundations are firmly grounded in a scientific view of the world (the importance of rational thinking and seeking objective evidence), which has led to questions about the efficacy of CBT for clients with more spiritually based beliefs [22,23].

There is little evidence to guide practice as ethnic minority groups are largely missing from efficacy studies that make up the evidence base for psychological treatments [24-26], particularly studies that focus on adolescents and children. Horrell examined the effectiveness of CBT with adult ethnic minority clients and demonstrated that, based on 12 studies, CBT appears to be an effective treatment for use with clients from ethnic minority backgrounds [27]. Seven of the 12 studies demonstrated significant treatment gains with CBT compared with a placebo or wait-list control. CBT was effective in reducing a range of symptoms such as Depression, Posttraumatic Stress Disorder, Generalized Anxiety Disorder and Panic Disorder. The authors recommend that further research needs to be conducted to determine whether CBT is a consistently effective intervention for ethnic minority groups [27].

Similarly, there is little published research regarding psychological interventions for Māori [28-30] and the attitudes and opinions of tangata whenua (indigenous people of New Zealand) towards the development of a CBT program [28]. Ideally, clinicians should provide evidence-based care to ethnic minority populations that has been tailored to make it sensitive and more acceptable to the culture of the individual receiving treatment [25].

Access to e-Therapies for Indigenous Young People

Adolescent ethnic minority groups have lower access rates when seeking professional treatment for depression [31-33]. Therefore, more needs to be done to facilitate easier access to treatments. With the proliferation in the use of technology there has been increased interest in the potential for cCBT to be used as a low-cost, easily accessible option for those in need of treatment [18]. It is thought cCBT has the potential to increase access to therapy for these indigenous youths if it can be delivered in a way that is acceptable and appealing to these young people. For example, cCBT can be customized to the end-user, the client's data can be easily accessed (with permission) and access to computers can reduce the cost of therapy [17]. In New Zealand, there are low access rates to mental health services by young people [34], cCBT has the potential to provide access to a therapeutic intervention, particularly for those people who are not accessing current services. The opinions and the attitudes of ethnic minority tangata whenua in relation to the development of a cCBT resource have only begun to be captured [35]. This study highlights the results of the user feedback from taitamariki in New Zealand who completed SPARX. SPARX is a cCBT program that teaches young people (12-19 years old) CBT skills to better manage their mild to moderate depressive symptoms. There are seven modules contained within the SPARX program and each module takes 20-30 minutes to complete. Users are engaged in a 3D environment where they must complete missions to progress to the next level. In each level there are challenges and puzzles to complete, one example is that the user must shoot down the Gloomy Negative Automatic thoughts. SPARX includes features that assist with the engagement of taitamariki. For example, SPARX contains an in-game environment that is particularly unique to New Zealand, there are Māori words used in SPARX, and there are Māori objects placed throughout SPARX, such as waka (canoe). There is also the ability to customize one's avatar to represent what a Māori person may look like to the participant. All these factors aim to increase the applicability of SPARX for Māori. For further information about SPARX please refer to the study by Merry et al [19].

Aims

The aim of this study was to follow up on a previous study that investigated taitamariki opinions in the process of codesigning the development of a beta version of SPARX [35]. This current study summarizes taitamariki experiences of completing the developed SPARX program.

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Methods

Ethics approval was granted by the Northern Regional Y committee (NTY 2009/01/03) of the New Zealand Ministry of Health. Consent was obtained from all participants and parental consent was sought for those under the age of 16 years. No inducements were offered.

Epistemological and Methodological Considerations

The first author (MS) conducted all the interviews and took a lead in analyzing this data. MS holds a critical realist position, having Māori whakapapa (genealogy) and was aware of following an indigenous process when collecting and interpreting the data [36].

Kaupapa Māori Methodology

Over the past three decades there has been an increasing awareness about the need to acknowledge Māori epistemology coupled with Māori ways of conducting research and, hence, the term "Kaupapa Māori research" was developed [37]. Western research traditionally holds an individualistic approach to epistemology. Māori healing practices differ to western approaches in that Māori will use karakia (prayer) as a key component to healing [38]. This highlights the reliance and incorporation of a God (Atua) or many deities. Accessing the spiritual dimension (wairua) for general wellbeing is an important dynamic in Māori life. Western psychological models such as CBT have tended to focus on an individual's internal psychological state, for example, a change in one's thoughts and feelings, which leads to improved mental health. However, the traditional Māori perspective has been to view the world in a collectivist way. Māori culture places an emphasis on the individual acting in a way that would seek to put whānau (extended family), and iwi (tribe) needs before individual needs. Therefore, western therapeutic approaches might have limited appeal or limited therapeutic power with Māori young people. With its analytic focus on individual thoughts, behaviors, and feelings, cCBT without processes of cultural connection might be considered antithetical to Māori worldviews. Alternatively, the use of Māori images, the use of story-telling, and opportunities for holistic learning processes embedded in an intervention may have some appeal. This has implications for research from a Māori worldview and this way of carrying out studies has come to be known as Kaupapa Māori research [37,38,39,40]. Since Kaupapa Māori research includes methodology, epistemology, theory, Māori tikanga (customs and protocols), MS was mindful about incorporating these aspects into this study. The observation of Māori protocol was important when meeting with the participants and is outlined in more detail below.

Recruitment of Participants

Two schools within the wider Auckland, New Zealand, area were asked if some of their students could be approached to participate in the study. These schools were chosen because they expressed interest in the study, had the necessary infrastructure, and had relatively large Māori populations. Participants for this study had accepted an invitation by school guidance counsellors to complete an open trial of SPARX and seven were screened for depression using the patient health questionnaire. Those in the mild to moderate range with scores of 10 to 19 inclusive and at low risk of self-harm were invited to complete baseline assessments, which included the Child Depression Rating Scale-Revised version (CDRS-R).

Data Collection

Once the participants had completed SPARX, all seven were asked to complete an interview which utilized a semistructured interview schedule (Multimedia Appendix 1). One participant declined the interview. Mihi whakatau (culturally formal method of beginning a meeting), karakia (prayers), and kai (food) were included in the interview process to incorporate a Kaupapa Māori methodology. All participants had completed all seven levels of the SPARX program. The topics of the questions included whether SPARX was helpful, whether they thought their mood had improved, what taitamariki thought about the content of the cCBT program, and which skills they found helpful. Opinions were sought regarding the main characters and the Māori designs in the SPARX program and the computer control mechanism used to move the main character. MS also explored whether whānau had supported taitamariki in their use of the SPARX resource. MS conducted all the interviews, which lasted approximately 30 minutes.

Qualitative Data Analysis

An inductive approach was incorporated while following Braun and Clarke's [41] six-step process of thematic analysis, which was used to identify, analyze, and present the main themes from the data. The participant interviews were transcribed and read through by MS to gain an initial understanding of the themes emerging from the data. The transcripts were then loaded into a computer software program (NVivo8).

Initial codes were generated during the first reading of the data and codes that were similar but distinct were kept separate. A second reading of the data confirmed the coding of the themes. To ensure reliability, another researcher read one-third of the transcripts and their themes were compared to the themes found by MS. Differing opinions about themes were discussed and an agreement was reached about which themes to include.

Results

Overview

The mean age of the participants was 14.67 years. Five of the participants were female (aged 14-16) and one participant was male (age 14). All the participants self-identified as being Māori. All of the participants in this study were part of a previous study [42], in which their depression symptoms were measured and monitored using the CDRS-R. A summary of scores at the three time points showed a reduction in depressive symptoms after completion of SPARX. The baseline mean score on the CDRS-R was 49.43 (SD 9.86), posttreatment 2-month mean score was 26.86 (SD 10.56), and the follow up 5-month mean score was 31.71 (SD 20). This was significant t (7)=3.930, P=.008 and effect size=1.49. The improvement was maintained at follow-up although the change from baseline was not as large as the change from post treatment t (7)=2.56, P=.043 and effect size=0.97. The score however dropped to a mean that was within the

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normal range. Six young people were interviewed via a semistructured interview process. A number of themes emerged from the data and were organized into five categories as shown in Table 1.

SPARX is Helpful as it Taught CBT Skills

All of the participants (N=6) who were interviewed described SPARX as being helpful. They stated that SPARX gave good advice and that it teaches real-life techniques and skills. The participants described skills such as relaxation and cognitive restructuring as being easy to use in everyday life. Taitamariki appeared surprised that the breathing techniques were especially beneficial for them.

> *Well, I have been feeling down sometimes and I have used the breathing techniques and all that type of stuff and it was actually really helpful.* [Female participant (P)1]

> *It was really good and helpful. Like when I needed to calm down using the technique, it actually helped a lot. Yes, so overall it was pretty good, the breathing in out one. At first, I thought it was a bit weird and I was like 'oh, my god, this is not going to work' but by just taking my time and working through it, it actually helped me.* [Female participant P2]

Three of the participants were able to give examples of how cognitive restructuring helped them, while also reporting that this was one of the more difficult concepts to understand.

> *Like when my Mum and Dad split up I thought it was my fault and I could have done something. And then after I did SPARX I did a lot of thinking and I couldn't have done anything because they weren't happy, and it was out of my control. So it helps me understand.* [Female P1]

> *Well, if I was thinking something negative, yes, I would go out for a walk and I would think about it until it became positive.* [Female P2]

> *It was like fun because of the game and it helped me with problems and solving. It was very good, it taught me not to think violent, just talk. This girl one of my cousin's friends, went to my house with my cousin and they were rude to my Mum. My Mum said, "tell her to come and say sorry." And I scooped her up and told her to say sorry. Oh no, I snapped down and told her I was going to smash her and then I thought about it and I said "Naw, that no good." Just go and say sorry to my Mum and it will be all good.* [Female P3]

Taitamariki were able to articulate how SPARX had helped to improve not just their mood but also their life and significant relationships:

> *It was actually really helpful. I had a lot of problems and it did help me a lot. I felt much more better and it taught me a lot of lessons. I am actually enjoying life now and I am still going through my up and downs, but it is a bit better. I am more happier and I don't feel down as much as I used to.* [Female P1]

> *But then I actually thought about it and I have actually come a long way from where I was. And SPARX had a big part of that, so that helped. When I first started it I was always sad, like practically every day, but now I am like happy and hang out with my friends and enjoy myself. Most days I am happy.* [Female P2]

The taitamariki were able to reflect on how it had helped their whānau. Some spoke about how they would talk to a sibling or a parental figure and suggest to them that they should play SPARX. Participants reported that little persuasion was needed for other whānau members to use SPARX.

Table 1. Categories and themes from analysis (N=6).

Categories	Themes
SPARX is helpful as it taught Cognitive Behavioural Therapy skills (N=6)	• SPARX was able to teach relaxation skills (N=4) • SPARX was able to teach cognitive restructuring skills (N=3) • SPARX helped improve mood and quality of life (N=3) • SPARX was able to help whānau members (N=3) • SPARX was able to increase participants' level of hope (N=2)
Māori designs assisted with the engagement of Māori adolescents (N=5)	• Māori designs were appropriate and appreciated (N=5) • The ability to customize the characters with Māori designs was beneficial (N=2) • Having Māori designs increased cultural identity (N=2)
Characters in SPARX provided hope and helpful advice (N=4)	• Characters were helpful (N=3) • The Guide was easy to understand (N=4) • The Bird of Hope character was helpful (N=2)
SPARX Game Design was enjoyable and provided challenging factors (N=3)	• Character control mechanism worked well (N=3) • Participants found the puzzles to be difficult (N=3)
SPARX Booklet was useful to record participants' thoughts and feelings (N=2)	• The booklet is a useful resource (N=2)

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> *Well, like during the holidays me and my Mum are going to do it together because she is going through a lot of stress as well. We would both sit down and do it and sort it out. I told Mum about the thing [SPARX] and she said that she would like to try it. I am hoping it will actually help her out and take less off her shoulders.* [Female P1]

> *I think my Mum. She has noticed the change as well and we have actually both put in the effort and things have been improving a lot more. We always used to fight and it used to be like if you are not going to change, why should I bother. So I just decided to make a change and ever since then my Mum has noticed and she has been nicer and she is actually putting in a good effort. I think SPARX has helped a lot in a way and really it was just up to me and my Mum but applying those skills actually helped. So that is a big part.* [Female P2]

Some taitamariki responded well to the psycho-education component in SPARX about having "hope." They reported that their mood had improved by being able to receive encouragement and adopt the new idea that life can be better if you have hope.

> *Like how they [characters in SPARX] always give you advice. Like for the hope one, that was really good. Like there is always hope and stuff.* [Female P1]

> *When I first started SPARX I was still feeling low and that but now that I have finished SPARX it has made me a bit happier and feeling all right. That my future is not going to be a negative future. It is going to be a positive future.* [Female P2]

Māori Designs Assisted With the Engagement of Māori Taitamariki

The majority of taitamariki (N=5) found the designs to be appropriate and felt the designs assisted them to engage with SPARX. The ability to customize their character helped to ensure this. Some taitamariki stated openly that the Māori designs helped to increase their Māori identity.

> *That is cool. It is different from other games, it can be fun, but it also has stuff from your culture and things you can relate to. So that was better.* [Female P1]

> *Yes, I think it does help because it is different from other games, they don't have anything like Māori culture. It is like unusual to see that kind of stuff in games. But having that makes it easier to relate to.* [Female P2]

Some taitamariki appreciated the ability to personalize their SPARX character with Māori designs on the clothing.

> *That was pretty cool [the customization process], but I think there should be more stuff because it is only like a couple of haircuts and skin tones and all that type of stuff.* [Female P1]

> *I got to make her look however I wanted, and I was able to choose the clothing and the hair style and that is really fun.* [Female P2]

Some taitamariki clearly had their identity affirmed by the inclusion of Māori designs within SPARX.

> *I liked them. They made me feel like I was neat. It opened my Māori in me. It makes me feel like I've got Māori in me and that everyone knows who I am.* [Female P1]

> *It is really cool. It is good to do something that has part of your heritage in it.* [Female P2]

Characters in SPARX Provided Hope and Helpful Advice

Taitamariki were able to describe how characters like the Guide, Mentor and Bird of Hope were all able to provide support and psychological education that was both helpful and hopeful.

Some taitamariki identified that it was beneficial to have nonplaying characters in SPARX. This provided an opportunity for taitamariki to practice the skills that they had been learning within SPARX.

> *It was pretty cool that you got to practice skills on them [nonplaying characters]. Like how do you make a win-win conversation and stuff, so that was pretty good.* [Female P1]

> *The lady [Mentor], those people that helped me out when I got stuck.* [Female P2]

Taitamariki identified strongly with the Guide, particularly because of the way he looked and sounded. This was clearly important for the Māori participants and enhanced their ability to relate to the Guide. Taitamariki reported that they felt the Guide was communicating personally with them. The Guide was also able to reinforce the learning that took place within SPARX.

> *He [Guide] actually looked like a Māori and it was easier for me to relate to because he had the New Zealand accent and the Māori accent and stuff. Sometimes he would say a few things in Māori so that was really good. He would explain it and then afterwards he would break it down and make it easier for me to understand. That helped a lot.* [Female P1]

> *That was good. It helped me out because if I didn't get what I was doing while I was actually doing it, it [the Guide] told me the proper meaning at the end.* [Female P2]

Some taitamariki benefited from having a character (the Bird of Hope) that embodied the concept of hope. Some taitamariki were encouraged by the function that the Bird of Hope provided.

> *It gave you information about what you are actually meant to do and how to handle these types of things, like thoughts.* [Female P1]

> *Oh, the bird is cute, hope. Yes, that was my little favorite thing on SPARKS is hope. Because she said, "I am always here to help you." It was so cute and*

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> *just the color of her. She looks so beautiful. I wish she was my pet.* [Female P2]

SPARX Game Design was Enjoyable and Provided Challenging Factors

Taitamariki reported that, while SPARX seemed like a game that was fun, it was able to be helpful by giving advice as well. Taitamariki thought that SPARX could have been longer and one male participant thought that the puzzles could have been a lot harder, in contrast to the views of most female participants. There was some mixed opinion about whether the character control mechanism in SPARX was easy to use. Some taitamariki felt that the current way to control the character could have been improved by using the keyboard arrows (instead of the mouse) to move the character.

> *It was actually really good, yes. It was really easy, you just had to click, and it would move to where you clicked. That was pretty good.* [Female P1]

> *I was thinking instead of using the mouse you could use the keyboard thing. Yes, keyboard arrows, yes. The general control, it was just when I had to make her run I had to double click it and then she would run then she would stop. Yes. It was medium.* [Female P2]

Some taitamariki found the puzzles difficult, though no one stated that it put them off completing SPARX as only one taitamariki completed fewer than all seven levels. Taitamariki were also provided with the answers to the puzzles (in the booklet that accompanied SPARX) so that they could continue with SPARX if they got stuck.

> *The puzzles were kind of hard. The challenges were good, yes. When the pieces got burnt and I had to sort them out, I found that hard.* [Female P1]

> *SPARX could have been longer and harder, as I only found one of the challenges to be difficult.* [Male P1]

SPARX Booklet was Useful to Record Participant's Thoughts and Feelings.

The SPARX booklet was designed as a learning aid so taitamariki could record their thoughts and feelings while they were progressing through the seven levels of SPARX.

> *It was easier to write it down than to keep it inside. I would probably write more about my feelings down on a piece of paper than keep it inside me.* [Female P1]

Discussion

Principal Findings

In this small study we have identified the potential importance of cultural components of eMental health interventions and have sought to incorporate indigenous youths' opinions and thoughts about the beta version of SPARX. The taitamariki interviewed here provided feedback on the applicability of SPARX for taitamariki experiencing mild to moderate depression. The Māori designs were found to be appropriate and useful and the ability to customize the characters with Māori designs appeared beneficial, as this seemed to enhance cultural identity. Taitamariki found SPARX to be helpful because it was able to teach relaxation and cognitive restructuring skills. It helped improve participants' mood and increased their levels of hope and, in some instances, was used by whānau members to good effect. The Guide was identified as Māori, and this appeared to increase engagement with the resource. In terms of the game design, the character control mechanism worked well. In general, participants found the puzzles to be difficult, while the booklet that accompanied the resource was found to be useful by these young people.

Many themes that emerged from the present study have reinforced the themes from an earlier research study that investigated taitamariki opinions about the initial design of SPARX [35]. This includes feedback that SPARX could teach CBT skills and that SPARX was like a computer game that could help with depression. A dominant skill that was highlighted again was the breathing relaxation exercise. Once taitamariki had the chance to complete all seven levels, the other CBT skill they described most frequently was cognitive restructuring. These findings suggest that participants were able to learn CBT skills without the aid of a therapist which is in line with other findings [43]. It is interesting that these taitamariki were very similar to the held mainstream views of cCBT [18]. These results suggest that SPARX is acceptable to the indigenous people of New Zealand and has the potential to address some of the unmet mental health needs of taitamariki [14,44]. Its availability as a public health resource could assist with the issue of access rates for services to indigenous youth, as adolescents rarely seek treatment for depression [31,32,33].

The findings from an initial study [35] in relation to the Māori designs enhancing the engagement and gaming experience for taitamariki were confirmed with this study. This was important because culturally adapted mental health interventions targeted to a specific cultural group can be much more effective than interventions provided to groups from a variety of cultural backgrounds [45]. These findings suggest that, for Māori females (as most of the participants were female), SPARX did meet the aim of being culturally applicable. The finding from a previous study that some taitamariki participants appreciated the ability to customize their own playing character within SPARX was confirmed. Some taitamariki reported that Māori designs affirmed their Māori identity, and this appeared to enhance the well-being of taitamariki.

Shepherd et al [35] suggested that a whānau perspective could be incorporated into SPARX. Although we were unable to do this because of funding and time constraints, it is apparent from this study that taitamariki included some whānau members who were interested in completing SPARX. Taitamariki reported that, once whānau members became engaged in SPARX, this was helpful with one person even suggesting that it led to an increase in the quality of whānau relationships. Edwards and McCreanor [46] have highlighted the importance of whānau for Māori young people and the need for intervention programs to incorporate whānau.

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Strengths of this Study

This study conducted interviews with taitamariki who provided important information about their experiences in completing SPARX. Very few studies have collected information about indigenous youth user feedback of a cCBT intervention. The findings from this group were similar to themes identified by the 19 taitamariki who participated in an earlier study concerning SPARX and taitamariki [35]. This is effectively a co-design process with the incorporation of young people's feedback on the beta version into subsequent iterations of SPARX.

Limitations of the Study

This is a small study and is exploratory in nature, limiting generalizability. A convenience sample was used, and the number of participants was not determined by data saturation. There is potential that these findings did not uncover the full range of experiences with SPARX. Participants were mostly female; we were not able to explore whether we had responded adequately to comments made by male participants in the first study who wanted more physical activities, such as fighting; shooting creatures or other characters; or activities such as fishing and skateboarding. Some of these were incorporated but feedback on this was limited. The one male participant who did complete the follow-up interview reported that the puzzles and challenges within SPARX were too easy.

Further Research

How SPARX could be used for whānau is an important area that warrants further research. The findings from this study suggest that some whānau may have gained psychological support serendipitously from the resource and that SPARX could play a role in strengthening whānau ora (family health). The concept of whānau ora is a New Zealand government strategy that is a part of *He Korowai Oranga: The Māori Health Strategy* [47]. This strategy highlights the importance of mental health and well-being for the overall health of Māori families.

Practice Implications

Taitamariki reported that they were able to learn CBT skills from SPARX and to improve their mental health through this form of pedagogy. The Māori designs were appropriate and useful, and the ability to customize the characters with Māori designs was beneficial as this enhanced cultural identity. These opinions were expressed within the earlier study as well and point to the need for therapeutic interventions directed towards taitamariki to be culturally appropriate and relevant to them. It is likely that this holds true for other indigenous groups. It is important that a much larger study be conducted to explore the efficacy of SPARX on this cohort.

Summary

The follow-up interviews from this study were important because they showed that the changes made resulting from feedback received from previous focus groups were mostly successful. Taitamariki found that SPARX helped improve mood and increased their levels of hope. Relaxation techniques were particularly helpful. SPARX was also able to help other whānau members. The Māori designs were appropriate and useful and the ability to customize the characters with Māori designs was beneficial as having Māori designs increased cultural identity connections. The characters in SPARX were helpful, for example, the Guide, which provided support and information that was easy to understand, and the Bird of Hope encouraged taitamariki to be hopeful.

Acknowledgments

The development and evaluation of SPARX was funded by the New Zealand Ministry of Health and supported by the Rotary Club of Downtown Auckland. MS was paid to work part-time on the development of SPARX by the University of Auckland. SPARX was developed in partnership with Maru Nihoniho and the team at Metia Interactive and is available nationally in New Zealand free of charge through funding from the Ministry of Health to the National Institute for Health Innovation.

Conflicts of Interest

MS and SM have a financial interest in SPARX. Currently SPARX is licensed to be sold in Japan and Canada. MS and SM may benefit from the sale of SPARX if a profit is generated. The intellectual property for SPARX is owned by Uniservices at the University of Auckland.

Multimedia Appendix 1

Youth E-Therapy Follow Up Interviews – Interview Guidelines for Taitamariki.

[PNG File, 54KB - games_v6i3e13_app1.png]

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Abbreviations

cCBT: computerized cognitive behavioral therapy
CBT: cognitive behavioral therapy
NZ: New Zealand
SPARX: Smart, Positive, Active, Realistic, X-factor thoughts

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Review

Head-Mounted Virtual Reality and Mental Health: Critical Review of Current Research

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Abstract

Background: eHealth interventions are becoming increasingly used in public health, with virtual reality (VR) being one of the most exciting recent developments. VR consists of a three-dimensional, computer-generated environment viewed through a head-mounted display. This medium has provided new possibilities to adapt problematic behaviors that affect mental health. VR is no longer unaffordable for individuals, and with mobile phone technology being able to track movements and project images through mobile head-mounted devices, VR is now a mobile tool that can be used at work, home, or on the move.

Objective: In line with recent advances in technology, in this review, we aimed to critically assess the current state of research surrounding mental health.

Methods: We compiled a table of 82 studies that made use of head-mounted devices in their interventions.

Results: Our review demonstrated that VR is effective in provoking realistic reactions to feared stimuli, particularly for anxiety; moreover, it proved that the immersive nature of VR is an ideal fit for the management of pain. However, the lack of studies surrounding depression and stress highlight the literature gaps that still exist.

Conclusions: Virtual environments that promote positive stimuli combined with health knowledge could prove to be a valuable tool for public health and mental health. The current state of research highlights the importance of the nature and content of VR interventions for improved mental health. While future research should look to incorporate more mobile forms of VR, a more rigorous reporting of VR and computer hardware and software may help us understand the relationship (if any) between increased specifications and the efficacy of treatment.

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KEYWORDS

virtual reality; well-being; behavior change

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Introduction

Development of Virtual Reality

Virtual reality (VR) is emerging as one of the key new technological tools in a digital revolution sweeping across the health care industry. Immersive VR allows users to interact with a computer-generated world, where the users natural sensory perceptions are replaced with a digital three-dimensional (3D) alternative [1]. To create an immersive VR system, a computer is used to generate an image, a display system is required to project the image, and, finally, a tracker is required to update the image based on users' movements. Traditionally, VR has been confined to laboratories as expensive and powerful computer(s) are needed to power it. VR, as we know it today, has been around for decades; the vision of VR was first realized by Ivan Sutherland in 1968 with the "Sword of Damocles" head-mounted display (HMD) and later by Morton Heilig with his multisensory Sensorama [2]. Failed attempts at VR systems by Nintendo (Virtual Boy) and Sega (Sega VR) in the 1990s and a further lack of development in the 2000s had many of its critics arguing that the technology was "dead" [3]. However, as noted by Olson et al [4], the video games industry has driven advances in graphics cards that are able to handle increasingly sophisticated 3D constructed environments. Furthermore, simultaneous developments in mobile phones and HMDs have made VR an accessible commodity for consumers. Lately, HMDs have markedly improved: an increased field of view (FoV), higher-resolution images, lightweight comfortable design, and an appealing price have added to its attraction [5]. Steed and Julier [6] described how they designed an immersive VR system around an Apple mobile phone (iPhone 4s), which had the computing power to act as a controller for a VR system. The implementation of gyroscope technology in mobile phones, which tracks user movements, has allowed HMDs to house mobile phones that act as the VR system itself. An example of the capabilities of gyroscope is the highly successful app "Pokemon Go" that tracks users' movements as part of an augmented reality experience [7]. Collectively, these developments have brought VR back into the public domain. Furthermore, low costs, innovative apps, and an increasing accessibility have captured the imaginations of researchers who have proposed its use in the treatment and assessment of a wide range of health care issues.

Building the Case for a Review

Evidently, VR is a rapidly emerging field of research. Since 2016, new HMDs from Oculus, HTC, HP, Acer, Dell, and Sony and the arrival of a range of cheaper mobile phone alternatives have acted as a catalyst for a new wave of VR research. Despite recent investment in Oculus by Facebook, indicating VR is here to stay, its popularity among consumers is unlikely to affect the quantity of research around it. VR research has been continuously expanding in a time where it has not been at the forefront of digital consumerism. Oculus' chief scientist Michael Abrash has suggested that in the next 5 years, we will see a new generation of VR products, which will operate with 4k screen resolution and with eye tracking that may allow for foveated rendering [8]. This prediction would appear to be coming partly true as companies race to produce HMDs with increasingly crisper resolution over their competition [9]. This suggests a potential new wave of VR products, thus, bringing down the prices of even the more sophisticated forms of VR today and making it an even more appealing tool for the health industry. With this in mind, now is the time to review the recent VR research, taking a view of what technology is being used and how it is being used.

Aims of This Literature Review

In this review, we aim to critically assess the current state of head-mounted VR research in relation to mental health. By doing so, we look to determine which conditions are more susceptible to VR interventions, which conditions need more attention, and in what form VR interventions are most effective. Our secondary aim is to understand more about VR used over the past 5 years and compare it to the new generation of VR in terms of accessibility and specifications. As there are indications that VR HMDs can be used at home as a self-help resource to provide a valuable tool for public health, in this review, we will assess head-mounted VR health research to date to determine whether this has been tested.

Key Concepts

HMD specifications are categorized into FoV, image resolution, and refresh rate (Hz). FoV refers to the view or surroundings a human can see without any eye movement. The human eye has a rotating FoV of up to 270° [10]; newer HMDs are attempting to create a FoV closer to that of the human eye. Currently, we can expect the Oculus Rift and HTC Vive to give an FoV of 110°, while some prototypes such as the Pimax 8k claim to offer an FoV of 200° [11]. Image or screen resolution refers to how clean and crisp the picture quality is; this is determined by the number of pixels in an image area and is reported by the number of pixels arranged horizontally and vertically [12]. For example, a screen resolution of 1280 720, which we refer to as 720p, is classified as high-definition (HD) ready. High-end HMDs today give a resolution between full HD (1080p) and QHD (1440p); again, both the Oculus Rift and HTC Vive offer a screen resolution of 2160 1200, which equates to 2,592,000 pixels per image. This method of reporting resolution has been key to selling televisions, which we see advertized as "full HD 1080p" or "4k." The investment that companies put into screen resolution can be seen by HTC's upgrade of the Vive to the Vive Pro, the two HMDs are essentially very similar with exception of the Vive Pro's increased 2880 1600 resolution. The refresh rate reported as hertz is the number of times a screen can change image. We refer to this refresh rate as frames per second (FPS); an increased FPS will give a more fluid motion of images. FPS is particularly important as we want movements to be realistic; an environment should act according to the user, which means the reduction of any lag between the users' input and the output of images. Furthermore, VR setups that operate below 90 FPS are more likely to induce nausea and disorientation [13].

We used a useful definition of mental health from a mental health foundation that defined it as:

> *A state of well-being in which the individual realises his or her own abilities, can cope with normal stresses*

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of life, can work productively and fruitfully, and is able to make a contribution to his or her community. [14]

The World Health Organization acknowledges that positive mental well-being is rooted within mental health; this state of well-being allows an individual to lead a fulfilling and productive life [15]. In this review, we aim to look at conditions that offer a scope to deliver psychological change that can make a meaningful difference to one's mental health. We excluded severe mental illnesses that require a more complex approach to treatment.

Virtual Reality and Mental Health

Health care and VR first met in the 1990s as a simulation tool for colonoscopy and upper gastrointestinal tract endoscopy simulation within medical education [16]. VR would have remained as a simulation tool for physicians and surgeons, but its interactive nature suggested it as an applicable tool for psychological change. For example, in the therapy of phobias, adaptability of virtual worlds means that contextually relevant virtual worlds can be created that are used to enable systematic exposure to feared stimuli [17]. The ability to precisely control stimuli has allowed VR ecological validity in its assessment of behaviors, emotions, and cognitions [18]. As a result, established effective psychotherapeutic approaches, such as cognitive behavioral therapy (CBT), are recreated within VR alongside exposure techniques [19]. This exposure is particularly effective as the goal of VR is to produce an "illusion of reality" [5]; however, for the patients, despite knowing that the computer environment is not real—a computerized illusion—their brains perceive the images and sound as real stimuli [1]. The broad reach of VR has enabled its use for treating schizophrenia, posttraumatic stress disorder (PTSD), social and generalized anxiety disorders, specific phobias, eating disorders, substance abuse, attention-deficit/hyperactivity disorder, depression, pain management, and psychological stress, as well as its use as part of a wide range of poststroke rehabilitation.

Methods

Design

Narrative syntheses were conducted on VR studies that were pertinent to areas of mental health [20]. The literature was critically assessed within the parameters of our review aims. Control and noncontrol studies were included, and studies varied from theory and assessment to treatment. Studies were featured if they appeared in peer-reviewed journals.

Inclusion and Exclusion

We set an inclusion timeframe from January 2012 to July 2017. A 5-year period was seen as sufficient enough to reflect the current state of the technology; this would allow us to assess studies that used both the new generation of HMDs and a range of older HMDs that have been in academia for the past decade. In line with this, studies were only included if they used an HMD. This meant excluding studies that used Cave Automatic Virtual Environment, the Computer-Assisted Rehabilitation Environment, and other projector systems without an HMD. As we focused on the systems used, if authors failed to disclose the type of VR used, or stated they used an HMD but provided no further information regarding its model or specifications, the study was excluded. Studies involving the use of two-dimensional (2D) virtual environments such as those seen in Second Life were excluded. Furthermore, augmented reality studies were not included as although augmented images are computer generated, the environment itself is not. Future VR may well feature an augmented experience within it [21]; however, at this time, the two technologies are separate, and this is reflected in this study's direction.

Mental health conditions were categorized as behavioral conditions that showed the potential to be modified upon intervention. In accordance with the International Statistical Classification of Diseases and Related Health Problems [22], we were primarily concerned with the areas of "Neurotic, stress-related, and somatoform disorders," "Behavioral syndromes associated with physiological disturbances and physical factors," "Mood disorders," and substance abuse. We included VR studies that featured any form of anxiety (generalized anxiety disorders, social anxiety disorders or specific phobias, and PTSD), depression, eating disorder (anorexia and binge eating), sleep disorders, and substance addiction or abuse. Pain management was also included as it has profound psychological and emotional consequences that can lead to depression and anxiety [23]. Severe mental disorders were excluded; a number of studies on psychosis were identified; however, due to its neurological origins as a state of brain development rather than a disease, psychosis was excluded from the study [24]. Autism was also excluded due it its neurodevelopmental origin. Finally, we excluded any rehabilitation studies, typically on stroke [25].

Search Strategy

The search strategy implemented in this review was conducted in 5 stages.

1. Key reviews in the area were identified; these contained broad mental health VR reviews to more condition-specific reviews.
2. The results and reference lists of these reviews were scanned to make an initial list of suitable studies.
3. Our own searchers were then carried out to identify any missed and more recent studies. The terms searched were: ["Virtual"] AND ["mental health" OR "well-being"]. This was followed with more condition-specific searches: ["Virtual"] AND ["Anxiety" OR "Social Anxiety" OR "Phobia" OR "Agoraphobia" OR "Arachnophobia" OR "Fear" OR "PTSD" OR "Depression" OR "Depress" OR "Stress" OR "Abuse" OR "Addiction" OR "pain" OR "Substance" OR "Eating" OR "Disorder" OR "Sleep" OR "Body Image" OR "Body" OR "sexual" OR "Dysfunction"]. Searches were conducted within "MEDLINE," "Journal of Medical Internet Research," "PsychINFO," "Google Scholar," and "Science Direct."
4. Screening was carried out upon the completion of a comprehensive list of studies. At this stage, studies were excluded based on publication date, condition type, and lack of immersive VR.

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5. The full texts of remaining articles were then assessed to find further reason for exclusion; at this stage, studies were typically excluded for not using an HMD or failing to disclose the type of VR used.

A full list of identified studies can be found in Multimedia Appendix 2.

Results

The Current State of Research

Head-Mounted Displays

The following findings have been compiled from 81 studies that used HMDs in interventions related to mental health; 18 HMDs appeared across six different areas of mental health. The eMagin z800 (n=34) was the most commonly used form of HMD appearing 34 times (Table 1). At the time of the review, the only quotable price for this product was US $1795, with no stock available in the UK. The z800 operates with a screen resolution of 800 600, a 40° diagonal FoV, and the standard refresh rate of 60 FPS. The second most commonly used HMD was the nVisor sx60 (n=8), which despite a higher screen resolution compared with the z800, still features a relatively low FoV compared with the consumer products used today. Two successful embodiment studies made use of HMDs with higher specifications: an nVisor sx111 with a resolution of 1280 1024 and a 111° diagonal FoV was used to provide compassion to crying baby avatars [26]. Keizer et al [27] used a second-edition Oculus Rift Developers Kit (960 1080 screen resolution and 100° nominal FoV) to reduce the level of body size misestimation among anorexic patients. Interestingly, the Oculus Rift was used in 5 of 22 pain management studies but in none of the anxiety studies, which may reveal a preference for certain specifications for certain medical conditions. Mobile phone VR was used once by Taskian et al who made use of Samsung's Gear HMD [28].

Anxiety

VR has been used as a form of exposure treatment (VRET). Its uses include the following conditions: social anxiety disorder [29-31]; PTSD for military veterans [32] and for World Trade Center attack [33] and assault victims [34]; a range of specific phobias, focusing on fear of flying [35] and fear of spiders [36-39]. Various forms of VRET are featured throughout the anxiety literature. Some studies have compared the efficacy of VRET versus *in vivo* exposure [30], while others have incorporated VRET with CBT and compared it with traditional CBT [29]. The contained exposure that VR provides has led to controlled studies where the effects of cycloserine and alprazolam have been tested for the treatment of PTSD [32,33,40]. Similarly, VR environments have been used for Theta burst stimulation [41] for those with spider phobia. The literature review revealed that VR exposure showed positive results on levels of anxiety and, generally, was at least as effective as *in vivo* exposure, although in some cases, the latter was slightly more effective [30]. A similar trend was noted for VR and CBT studies, with Bouchard et al [29] finding an increased level of effectiveness for VRCBT over traditional CBT. In addition, Malbos et al [42] found that when treating anxiety for agoraphobia, VRET was just as effective in reducing anxiety as VRET with CBT combined. VR has been proven to be a markedly effective tool to induce fear to stimuli [19], and it is also able to predict future levels of PTSD severity [34] and diagnose patients with the condition [43].

Pain Management

VR has been used as a distraction tool for pain management. Different forms of VR distractions have been used for burn wound pain [44-47], phantom limb pain [48,49], cold pressor pain [50,51], dental pain [52,53], neck pain [54,55], back pain [56], and cystoscopy [57] as well as for the assessment of analgesia [58-60] and kinesiophobia [56,61]. Distractions ranged from coastal walks [52] and target-aiming tasks [61] to a Sonic the Hedgehog Nintendo video game [51]. Other treatments were dictated by the pain they were treating; visual limb distractions were used for phantom limb pain [48,49]. Bahat et al used VR to manage impairments in cervical kinematics, which is commonplace for those with neck pain [54]. Two studies reported VR distraction to be more effective at reducing perceived pain than controls, which included passive 2D distractions [38,44]. In contrast, Sil et al reported that an interactive video game without VR was equally as effective at reducing pain as the same game with VR [51]. Piskorz et al focused on the varying levels of complexity within VR distraction tasks and concluded that more complex tasks were more effective at reducing the levels of pain [50]. In total, we identified 22 studies; VR delivered through HMDs was frequently seen as the most effective method to distract from pain and, at worst, was equally as effective as controls.

Stress

Stress was the primary target and depression the secondary in Shah et al's VR mood induction procedure study [62]. That study did not have a control group, but the VR-based stress management program did show a decrease in the levels of depression and stress. This result was achieved by face-to-face psychoeducation that centered on relaxation practice and on how to manage stress; relaxation techniques were then practiced in VR. The Trier Social Stress Test (TSST), a paradigm used for inducing psychosocial stress, was successfully implemented in VR [63]. Designed to induce rather than reduce stress, VR-TSST showed a marked increase in peripheral and subjective physiological reactions compared with *in vivo* TSST. Finally, VR-based mindfulness apps may also prove to have a positive effect on stress [64].

Depression

We identified only one intervention that had depression as the primary target [36]. Patients delivered a compassionate message to a crying baby avatar and then received the same message while embodied as the baby. After three repetitions of the scenario, patients demonstrated a marked reduction in depression severity and self-criticism, with a substantial increase in self-compassion.

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Table 1. Head-mounted display (HMD) specifications.

Type	Resolution	Hz	Field of View	Number of Studies
eMagin z800	800 × 600	60 Hz	40°	34
nVisor SX60	1280 × 1024	60 Hz	60°	8
nVisor SX111	1280 × 1024	60 Hz	111°	4
nVisor ST50	1280 × 1024	60 Hz	50°	1
Sony HMZ-T1	1280 × 720	60 Hz	51.6°	1
5DT HMD	800 × 600	N/A[a]	40°	3
VisuaStim	1280 × 1024	85 Hz	40°	1
Kaiser XL 50	1024 × 768	60 Hz	50°	1
VR1280	1280 × 1024	60 Hz	60°	1
Virtual Realities VR HMD pro 3D-42	800 × 600	N/A	42°	1
Pro	640 × 480	60 Hz	71.5°	2
Vuzix iWear VR920	640 × 480	N/A	N/A	5
Vuzix VR1200	N/A	N/A	N/A	2
VFX3D	640 × 480	N/A	35°	1
Sensis Zsight	1280 × 1024	60 Hz	60°	2
V6 by Virtual Research Systems	640 × 480	60 Hz	60°	1
V8 by Virtual Research Systems	640 × 480	60 Hz	60	1
Oculus Rift DK1	640 × 800	60 Hz	110°	1
Oculus Rift DK2	960 × 1080	75 Hz	100°	6
ITV goggles ITG Wideview Xl edition	N/A	N/A	N/A	1
Samsung Gear VR	2560 × 1440[b]	60 Hz	96°	1
i-glasses 920HR	N/A	N/A	35°	1
Kaiser Optics SR80a	N/A	N/A	N/A	1
Capable HMDs commonly sold on the market today				
HTC Vive	2160 × 1200 (combined)	90 Hz	110°	N/A
HTC Vive Pro	2880 × 1600 (combined)	90 Hz	110°	N/A
Oculus Go	1280 × 1440 (per eye)	72 Hz	N/A	N/A
PlayStation VR	1920 × 1080	90 Hz (120 Hz in cinema mode)	100° (approximately)	N/A
Samsung Odyssey	1440 × 1600 per screen	90-60 Hz	110°	N/A

[a]N/A: not applicable.

[b]Super AMOLED (active-matrix organic light-emitting diode) and dependent on mobile phone used.

Eating Disorders

Studies on eating disorders included those on body image disturbance (BID) [65,66], anorexia, and bulimia nervosa [36,67]. Gutiérrez-Maldonado et al [67] compared this form of VR with a more immersive VR that used the Oculus Rift Developers Kit 1. The study found immersive VR to be slightly more effective at reducing food cravings compared with nonimmersive VR. Mountford et al [66] concluded that dieters reported higher social evaluative concerns compared with nondieters. In addition, Purvis et al [65] found that women reported higher levels of body satisfaction in a VR environment than in control conditions. In an innovative study, Keizer et al [27] created a full-body illusion treatment and concluded that disturbed experiences of the body in patients with anorexia nervosa could be altered with VR.

Addiction and Substance Abuse

HMDs have been used to deliver exposure therapy to help treat tobacco addiction. Four studies investigated tobacco addiction [68-71]; one focused on relapse prevention of tobacco consumption [72] and one on nicotine dependence [73]. The remaining studies focused on gambling addiction [74,75] and adolescent risk reduction [76]. Virtual reality cue exposure therapy (VR-CET) was used to various degrees of success in the majority of studies. Pericot-Valverde et al [68] found

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VR-CET to be as effective as traditional CET for smoking cessation and, in a later study [69], stated that VR-CET might be more beneficial toward certain individual variables, particularly age. Forms of CET were used in 6 out of 8 studies, and VR-based cue reactivity assessment approach was used [73] to demonstrate the feasibility of cue exposure within VR to treat nicotine dependence. Lister et al [74] did not test the efficacy of VR to treat gambling addiction but, nevertheless, constructed a VR environment to demonstrate how goal setting within gambling can lead to a chasing behavior that can amount to large financial losses for gamblers. Another study compared the efficacy of CBT against VRET for preventing relapses in nicotine dependence [58].

Discussion

This review confirms that HMDs have been used to treat mental health in different ways. VRET was one type of intervention that was consistently used across different conditions. VRET interventions with and without CBT content have been implemented for therapy of anxiety, PTSD, stress, eating disorders, and substance addiction. VR excels in its advantage of being able to draw on both audio and interactive visual stimuli, making the fearful stimuli appear as real as possible. In addition, CBT delivered in VR has shown consistent positive results; the accurate adaption of relevant stimuli allows CBT to pinpoint troublesome behaviors. The merging of VR and mobile phones is a timely collaboration, and stress management apps for mobile phones have been described as “incremental acquisitions” to cope with daily-life stresses [77]. The release of cost-effective HMDs, such as Google Cardboard, along with mobile phone–compatible Samsung Gear VR is paving the way for an accessible form of health promotion that encompasses the mobile nature of mobile phones and the interactive exposure of VR. However, this review revealed only one occasion when a mobile HMD was used [38]. A rise in cryptocurrencies has implied that the cost of personal computer (PC) graphics cards that power VR graphics is increasing rather than declining as once expected [78]; moreover, added with the announcement of Oculus Go [79], it highlights the need to demonstrate the clinical capabilities of mobile VR that does not rely on high-end PCs. Future research should focus on testing a VR experience that can be used at home; the cheaper alternatives discussed would be an ideal starting location.

Lindstrom [80] highlighted the work of Aaron Antonovsky’s “Salutogenesis” in which he points to a method of “generating” health and emphasized an important difference between public health and biomedical models: health promotion focuses on the resources toward health over the cautionary tales of risk and disease. Early results in the treatment of stress suggest that VR is an ideal platform to combine exposure to relaxation and provide psychoeducation [62]. There is a need to investigate how the core features of VR can create exposure to positive stimuli that help promote health. VR research into pain management has highlighted how positive VR experiences can provide a pain-relieving distraction. If exposure to pleasant stimuli in relaxing environments is as successful as evoking fear during deliberately troubling environments, VR could prove to be an important novel platform for providing people the resources toward health. While nonimmersive virtual environments were excluded from this review, it is worth noting how health promotion became a prominent feature of the computer program Second Life [81], as users were able to interact with bulletin boards, multimedia productions, power points, health videos, and links to health-related Web pages. These acted similar to psychoeducation in the sense that both information and education were offered [82]. Offering a more immersive experience than Second Life, there is reason to believe that similar health promotion tactics could succeed in a VR environment. Further research is needed to determine whether exposure to positive stimuli is as effective for mental health as exposure to negative stimuli is for a psychological change.

The success of VR in the treatment of anorexia- and depression-focused embodiment studies [27,36] highlights its effectiveness in treating conditions that can be “visual” for the sufferers. While there is no evidence to suggest that newer VR systems—with higher screen resolution and FoV—are more clinically successful than older VR systems, HMDs with higher specs may be better equipped to execute successful condition-focused interventions. For example, the Oculus Rift with its 110° FoV was not used in any of the anxiety studies but appeared in 5 of the 22 pain management studies. This could be attributed to the preferences of the authors; however, it could be argued that the Rift with its larger FoV is more suitable for distraction interventions, whereas this increased FoV is not as crucial when trying to evoke a fearful reaction in someone with anxiety. It is also hard to determine whether VR HMDs are being used to their full potential. The reporting of materials in the reviewed literature was frequently limited, and we even excluded studies for failing to specify the type of VR used; however, the specifications of PCs being used to power VR were even less frequently reported. All HMDs featured in Table 1 allow images to be displayed at least 60 FPS, with newer models allowing for 90 FPS. Many computer systems are unable to reach this potential as the experience of VR being powered by a 2GB Nvidia GeForce GTX 950 graphics card will be different to a newer 11Gb GeForce GTX 1080Ti. This matters because we know that frame rate judder caused by lower FPS can be a catalyst for motion sickness [83]. Thus, we recommend the use of FPS tools, as suggested [84], to provide more rigor to material and method reporting. In the interest of making the research replicable, we also recommend the development of a framework for reporting technical specifications of VR.

The state of research suggests that VR cannot be a clinical tool itself and, instead, its success relies on the content it provides a platform for. Complex VR systems backed by PCs with high graphical and processing power to build detailed and adaptable environments allow the content of the intervention to be complemented further. The most common HMD was the eMagin z800, which in the UK is not an accessible product. In public health context, it is imperative that commonly sold HMDs are used with VR apps that can be used for self-help and to promote health. This review points to VR as a useful method of modifying the behavior in an effort to enhance mental health; the challenge now is to apply this to accessible products, which the public can use at home, work, and on the move.

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The results of this review suggest the potential efficacy of VR to provide a platform for improved mental health. VR has demonstrated some compatibility with proven psychological interventions, but combined, they illustrate a potential for a real positive behavior change for a range of mental health conditions. The current state of research does not illustrate VR's ability to improve mental health on its own; instead, it highlights the importance of the condition-oriented content within VR interventions.

However, the specifications of HMDs and the computers that power them are still important when trying to improve mental health using VR. Although increases in FoV have brought us closer to FoV of the human eye, an improved FPS may decrease the chances of motion sickness for some users. Currently, VR's strengths are being used for exposure therapy, as successful interventions in the treatment of anxiety, phobias, and PTSD have been demonstrated. In addition, VR-induced distraction has proven to be a remarkable development in pain management. The lack of studies surrounding stress and depression, despite positive initial outcomes, highlights VR's infancy in some areas of mental health. To help understand more about the relationship between VR systems and its efficacy as a mental health tool, we recommend a thorough reporting of HMD and computer specifications. Finally, there is a need to design interventions that make the most of VR's increasing mobility, as self-help VR tools could prove to be a valuable asset for mental health services. Thus, researchers must make the most of a rapidly developing medium that is seeing advances in equipment; this will act as a catalyst to develop increasingly detailed and novel interventions that push the boundaries of virtual presence. By achieving this, VR has the potential to radically change the way we modify problematic behaviors that affect our mental health.

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Conflicts of Interest

None declared.

Authors' Contributions

The study was conceptualized by all four authors. Furthermore, data was curated, formal analysis was performed, and methodology was devised by all four authors. Project administration & critical supervision was performed by MG, MKB, and HvW. The original draft was prepared by SJ, and revisions and editing were performed by all four authors.

Multimedia Appendix 1

Literature table.

[PDF File (Adobe PDF File), 210KB - games_v6i3e14_app1.pdf]

Multimedia Appendix 2

Head-mounted display (HMD) virtual reality (VR) use as reported in literature 2012-2017 (n=81).

[PDF File (Adobe PDF File), 83KB - games_v6i3e14_app2.pdf]

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Abbreviations

CBT: cognitive behavioral therapy
FoV: field of view
FPS: frames per second
HD: high definition
HMD: head-mounted display
PTSD: posttraumatic stress disorder
TSST: Trier Social Stress Test
VR: virtual reality
VRET: virtual reality exposure treatment

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Original Paper

Video Games as a Potential Modality for Behavioral Health Services for Young Adult Veterans: Exploratory Analysis

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Abstract

Background: Improving the reach of behavioral health services to young adult veterans is a policy priority.

Objective: The objective of our study was to explore differences in video game playing by behavioral health need for young adult veterans to identify potential conditions for which video games could be used as a modality for behavioral health services.

Methods: We replicated analyses from two cross-sectional, community-based surveys of young adult veterans in the United States and examined the differences in time spent playing video games by whether participants screened positive for behavioral health issues and received the required behavioral health services.

Results: Pooling data across studies, participants with a positive mental health screen for depression or posttraumatic stress disorder (PTSD) spent 4.74 more hours per week (95% CI 2.54-6.94) playing video games. Among participants with a positive screen for a substance use disorder, those who had received substance use services since discharge spent 0.75 more days per week (95% CI 0.28-1.21) playing video games than participants who had not received any substance use services since discharge.

Conclusions: We identified the strongest evidence that participants with a positive PTSD or depression screen and participants with a positive screen for a substance use disorder who also received substance use services since their discharge from active duty spent more time playing video games. Future development and evaluation of video games as modalities for enhancing and increasing access to behavioral health services should be explored for this population.

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KEYWORDS

behavioral health; replication; veterans; video games

Introduction

Behavioral health issues such as posttraumatic stress disorder (PTSD), depressive disorders, and substance use disorders (SUDs) are common diagnoses among veterans from recent conflicts in Iraq and Afghanistan [1,2]. However, at best, only half of the veterans with a documented behavioral health need actually receive behavioral health services [3,4]. Moreover, nearly 40% of the veterans from recent conflicts in Iraq and Afghanistan have never sought services through the Veterans Health Administration (VHA) for any reason since separation from active military duty [5,6]. Young adult veterans are particularly at risk for unmet behavioral health needs, as they are less likely to seek behavioral health services than older veterans [7,8], have higher rates of behavioral health issues than older veterans [1], and report poorer behavioral health than young adult civilians [9]. Improving the reach of behavioral health services to young adult veterans is consequently a policy priority.

Young adult veterans report multiple barriers to seeking and receiving behavioral health services in traditional settings and formats. These include inconvenience of appointments, concerns about high costs, perceived stigma from peers, beliefs that they can handle symptoms on their own, and living in rural settings that are far from care settings [3,4,10-14]. Expanding beyond traditional care settings and developing innovative means of engagement can help address unmet behavioral health needs.

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Video games have the potential to improve the reach of behavioral health services [15], including those who have currently unmet behavioral health needs or face difficulty accessing treatment [16]. Given their increasing popularity [17], research on video game use is increasingly shifting from a focus on its potential negative impacts (eg, exposure to violence) to its potential cognitive, emotional, social, and health benefits [18,19]. Specifically, video games are increasingly used for health-related interventions, given their engaging and entertaining format [20,21] and their versatility across different platforms or environments such as consoles, computers, and mobile phone apps [15]. Recently, these apps have been extended to serve as an alternative or additional form of treatment for behavioral health [22,23]. For example, a computer video game that incorporates evidence-based cognitive behavioral therapy was found in a randomized trial to be both an appealing and efficacious treatment for adolescent depression [16,24].

In this exploratory study, we replicated analyses from two cross-sectional, community-based surveys to explore the plausibility of video games as a modality for behavioral health services for young adult US veterans. The lack of data on veteran video game playing precluded us from making clear a priori hypotheses regarding the prevalence of video game playing in the sample. As video game-based interventions appeal more to those who play video games generally [16], the lack of familiarity with and available leisure time to play video games can serve as key barriers to their use for behavioral health services [17]. We therefore used the time spent playing video games as a proxy for familiarity with and time available for video games. We specifically examined differences in time spent playing video games by whether participants screened positive for a behavioral health issue (ie, alcohol misuse, depression, and PTSD) and received the required behavioral health services.

Methods

Study Procedures

Data presented in this manuscript are from two surveys conducted as part of a larger randomized controlled trial (RCT) of a Web-based normative feedback intervention for heavy drinking young adult veterans [25,26]. We collected data on the video game behaviors of young adult veterans for the comparator intervention (ie, attention-matched normative feedback on video game behaviors); we did not prespecify any of the analyses on the video game behavior data reported in this manuscript. The Human Subjects Protection Committee at the RAND Corporation approved all procedures for both studies.

Participant Recruitment and Eligibility

We recruited nontreatment seeking young adult (age, 18-34 years) veteran participants in both samples through advertisements on Facebook that did not mention video games or behavioral health. We have previously reported comprehensive details of the recruitment strategy and methods for validating veteran participants for Study 1 [27] and Study 2 [28]. We conducted all procedures online.

Study 1

Study 1 involved a survey on the behavioral health symptoms of a large general sample of young adult veterans recruited outside of VHA settings. We targeted a series of Facebook ads to users between the ages of 18 and 40 years who expressed an interest in (ie, “liked”) specific veteran or military Facebook pages as well as media (movies, TV shows, and video games) related to military (eg, Act of Valor, Generation Kill, Call of Duty). Interested Facebook users who clicked on ads were directed to a Web-based informational statement and consent form. Eligible participants who consented to participate were first verified to be actual veterans using data check procedures we have described in detail elsewhere [27], before completing a longer Web-based survey of the measures described below.

Study 2

Study 2 involved a screening and baseline survey for an RCT of a brief, Web-based, personalized normative drinking intervention, where participants saw feedback about their drinking (intervention) or video game playing behavior (control) compared with their peers. As with Study 1, participants clicked on targeted Facebook ads, although we did not include ads targeting any media regarding video games (eg, Call of Duty). The eligibility criteria were the same across studies, except that participants in Study 2 needed to score at least a 3 (females) or 4 (males) on the 10-item Alcohol Use Disorders Identification Test (AUDIT) [29]. These AUDIT cutoff scores were selected to include participants in the larger RCT who drank at moderate to high levels and were at risk for hazardous or problem drinking [30,31].

Participant Characteristics

Study 1

We recruited 1023 young adult veterans overall, of whom 552 (53.9%) reported playing video games at least 1 hour per week. To match the eligibility criteria of Study 2, we restricted the subsample who reported playing video games at least 1 hour per week to the 350 veterans who also had scores of at least 3 (females) or 4 (males) on AUDIT.

Study 2

We recruited 784 young adult veterans overall. Because we were interested in veterans who reported any video game use for analyses in the current study, we restricted our sample to 582 veterans (74.2%, 582/784) who reported playing video games at least 1 hour per week.

Materials

Data Collection

For both studies, we collected information on demographics, behavioral health symptoms, behavioral health services use, and video game behaviors. In this manuscript, we report analyses on similar constructs assessed in both Study 1 and Study 2, although we operationalized several constructs using different measures (Multimedia Appendices 1 and 2).

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Demographics

Participants in both studies filled out the same measures regarding age, gender, ethnicity or race, education, marital status, number of children, annual household income, and branch of military service.

Behavioral Health Symptoms

Participants completed brief screening measures for behavioral health problems.

Posttraumatic Stress Disorder Symptoms

In Study 1, we assessed PTSD symptoms with the 4-item Primary Care PTSD scale (PC-PTSD). A score of 3 or higher (ie, participants endorsed "yes" for 3 of the 4 PTSD symptoms) on PC-PTSD indicated a probable diagnosis of PTSD [32]. In Study 2, we assessed PTSD symptoms in the past month with the 20-item PTSD Checklist for Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (PCL-5). Items in PCL-5 ranged from 0 "not at all" to 4 "extremely," with a cutoff score of 33 or higher as screening for a probable diagnosis of PTSD [33].

Depression Symptoms

In Study 1, we assessed depression symptoms with the 2-item Patient Health Questionnaire (PHQ-2). Participants rated two symptoms (ie, "little interest or pleasure in doing things" and "feeling down, depressed, or hopeless") from 0 "not at all" to 3 "nearly every day" for the past 2 weeks. A score of 2 on the PHQ-2 indicated screening for a depression diagnosis [34]. In Study 2, we assessed depressive symptoms for the past 2 weeks with the 8-item Patient Health Questionnaire (PHQ-8). Items on the PHQ-8 ranged from 0 "not at all" to 3 "nearly every day," with a cutoff score of 10 or higher as screening for a probable diagnosis of a major depressive disorder [35].

Alcohol Use

In both studies, we assessed alcohol use disorder (AUD) symptoms in the past year using AUDIT [29]. A score of 8 or higher indicated hazardous drinking. Participants in both studies also reported for the past 30 days, the number of days the participants drank; the amount of alcohol consumed per occasion; heavy drinking days, that is, days when they consumed more than 4 drinks for females or more than 5 for males; and largest number consumed on any one occasion. We assessed consequences with the Brief Young Adult Alcohol Consequences Questionnaire [36], where participants indicated if they experienced each of the 21 consequences related to drinking in the past month.

Cannabis Use

We asked participants if they used any cannabis or marijuana in the past 6 months (yes or no), and if so, how many days in the past month did they use. The Study 1 survey referred to the drug as cannabis and the Study 2 survey referred to it as marijuana.

Behavioral Health Services Use

In both studies, participants indicated whether they had attended any appointments (in any setting: VHA, Vet Centers, or community providers) for mental health concerns or substance use concerns since discharge from active duty in the past month or year.

Video Game Behaviors

In both studies, participants indicated the typical number of hours they played video games per day, hours they played video games per week, and days they played video games per week in the past 30 days using slightly different methods. In Study 1, participants indicated how many hours on each day of the week they typically played video games, while in Study 2, they responded to 3 single items about the hours per day, hours per week, and days per week they typically played video games. In both studies, participants were asked to consider computer-based games, console video games, arcade video games, mobile phone or tablet games, or Web-based JavaScript games.

Analysis Procedures

We first calculated descriptive statistics for, and differences in, demographics between Study 1 and Study 2 samples. Then, we used Welch's *t* test to examine whether participants who screened positive for a behavioral health issues played video games to a different degree than those who did not screen positive. Lastly, among participants who screened positive for behavioral health issues, we used Welch's *t* test to examine whether those who received services played video games to a different degree than those who did not report using any services. We examined the results from the analyses on behavioral health and video game behaviors in two ways [37,38]. First, we assessed whether the "existence" (statistical significance) and direction of any differences were replicated across both studies: (ie, $P<.05$ in same direction in both studies). Second, we calculated the fixed-effect meta-analytic estimate for the mean difference in effects by pooling differences from both studies [39].

Results

Demographics

We included 350 participants from Study 1 and 582 participants from Study 2 (see Table 1). The average ages of participants in Study 1 and Study 2 were 28 and 29 years, respectively. Study 1 had significantly more males (323/350, 92.6%) than Study 2 (505/582, 86.8%), $\chi^2_1=6.8$, $P=.009$ (N=931). Study 1 had significantly more Hispanic participants (72/349, 20.6%) than Study 2 (60/582, 10.3%), $\chi^2_1=19.1$, $P<.001$ (N=931). Study 2 had more White participants (499/582, 85.7%) than Study 1 (273/350, 78.0%), $\chi^2_1=8.7$, $P=.003$ (N=932). A substantial majority of participants in both Study 1 (64/350, 18.3%) and Study 2 (116/582, 19.9%) had not earned a college degree, although more participants in Study 1 (163/350, 47%) were currently in college than in Study 2 (200/582, 34.4%), $\chi^2_1=13.2$, $P<.001$ (N=932). In both studies, the modal annual household income was US $25,000 to US $49,999; about half of the participants in each study were married, with an average of one child per veteran. Among those with children, the average number of children living at home was 2. The majority of participants in both studies served previously in the army, with about a quarter previously serving in the marines.

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Table 1. Participant characteristics.

Demographics	Study 1 (N=350)	Study 2 (N=582)	*P* value[a]
Age, mean (SD)	28.4 (3.4)	28.7 (3.4)	.11
Male, n (%)	323 (92.6)	505 (86.8)	.009
Hispanic ethnicity, n (%)	72 (20.6)	60 (10.3)	<.001
Race, n (%)			**.003**
White	273 (78.0)	499 (85.7)	
Other	77 (22.0)	83 (14.3)	
Education, n (%)			**.60**
Some college or less	286 (81.7)	437 (80.1)	
College graduate	64 (18.3)	116 (19.9)	
Currently in college, n (%)			**<.001**
No	187 (53.4)	382 (65.6)	
Yes	163 (46.6)	200 (34.4)	
Annual household income, n (%)			**.29**
<US $10,000	29 (8.3)	32 (5.5)	
US $10,000 to US $14,999	29 (8.3)	46 (7.9)	
US $15,000 to US $24,999	70 (20.0)	90 (15.5)	
US $25,000 to US $49,999	121 (34.6)	238 (40.9)	
US $50,000 to US $99,999	84 (24.0)	142 (24.4)	
US $100,000 to US $149,999	14 (4.0)	28 (4.8)	
US $150,000 to US $199,999	3 (0.9)	3 (0.9)	
US $200,000 +	0 (0.0)	1 (0.2)	
Married, n (%)	186 (53.1)	278 (47.8)	.13
Number of children, mean (SD)	1.4 (1.5)	1.3 (1.4)	.14
Number of children living at home, mean (SD)	1.7 (1.1)	1.7 (1.3)	.82
Branch of service, n (%)			**.25**
Air Force	22 (6.3)	57 (9.8)	
Army	215 (61.4)	348 (59.8)	
Marine Corps	87 (24.9)	129 (22.2)	
Navy	26 (7.4)	48 (8.2)	
Mental health, n (%)			
Positive screen for posttraumatic stress disorder	152 (43.4)	227 (39.0)	.21
Positive screen for depression	169 (48.3)	271 (46.6)	.66
Alcohol use			
Positive screen for disorder, n (%)	151 (43.1)	174 (29.9)	<.001
Total drinking days, mean (SD)	10.4 (9.1)	12.4 (8.8)	.001
Drinks per drinking day, mean (SD)	4.8 (4.3)	4.7 (3.3)	.77
Heavy drinking occasions, mean (SD)	4.6 (6.2)	5.8 (7.2)	.01
Max drinks on a drinking day, mean (SD)	8.5 (6.0)	9.4 (6.0)	.03
Alcohol consequences, mean (SD)	7.8 (7.1)	7.6 (6.8)	.58
Cannabis use			
Cannabis use in past 6 months, n (%)	106 (41.9)	169 (29.0)	<.001
Total number of cannabis use days, mean (SD)	9.9 (11.4)	3.3 (8.6)	<.001

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Demographics	Study 1 (N=350)	Study 2 (N=582)	*P* value[a]
Any behavioral health services receipt, n (%)			
Services since discharge	183 (52.3)	338 (58.1)	.10
Services in past year	119 (34.0)	238 (40.9)	.04
Services in past month	42 (12.0)	101 (17.4)	.04
Mental health services receipt, n (%)			
Services since discharge	175 (50.0)	320 (55.0)	.16
Services in past year	116 (33.1)	228 (39.2)	.08
Services in past month	42 (12.0)	98 (16.8)	.06
Substance use services receipt, n (%)			
Services since discharge	67 (19.1)	121 (20.8)	.60
Services in past year	31 (8.9)	66 (11.3)	.28
Services in past month	1 (0.3)	18 (3.1)	.007
Video game use, mean (SD)			
Total hours spent playing per day	2.3 (1.8)	3.5 (3.2)	<.001
Total hours spent playing per week	12.8 (13.5)	18.4 (21.9)	<.001
Total days spent playing per week	5.0 (2.3)	4.7 (2.2)	.046

[a]*P* values are reported from the Welch's two-sample *t* test for continuous measures and chi-square test for categorical measures.

Behavioral Health

Similar proportions of patients screened positive for PTSD (Study 1, 152/350, 43.4%; Study 2, 227/582, 39.0%) and depressive disorder (Study 1, 169/350, 48.3%; Study 2, 271/582, 46.6%). Participants consumed about 5 drinks per drinking day. Screening positive for an AUD was more likely for participants in Study 1 (151/350, 43.1%) than in Study 2 (174/582, 29.9%), χ^2_1=16.3, *P*<.001 (N=932). However, compared with participants in Study 1, participants in Study 2 drank more days in the past month (Study 1 mean 10.4 [SD 9.1]; Study 2 mean 12.4 [SD 8.8]; t_{715}=−3.2; *P*=.001), drank more drinks on their peak drinking day (Study 1 mean 8.5 [SD 6.0]; Study 2 mean 9.4 [SD 6.0]; t_{662}=−2.2; *P*=.03) and had more heavy drinking days (Study 1 mean 4.6 [SD 6.2]; Study 2 mean 5.8 [SD 7.2]; t_{743}=−2.5; *P*=.01). Compared with participants in Study 2, more participants in Study 1 used cannabis in the past 6 months (Study 1, 106/253, 41.9%; Study 2, 169/582, 29.0%), χ^2_1=12.6, *P*<.001 (N=835), and on more days in the past month (Study 1 mean 9.9 [SD 11.4]; Study 2 mean 3.3 [SD 8.6]), t_{100}=5.01, *P*<.001. Approximately half of the participants reported any use of behavioral health services since their discharge, a little over a third reported use within the past year, and less than one-fifth reported use within the past month.

Video Game Behaviors

Participants in Study 1 reported playing video games fewer hours per day (Study 1 mean 2.3 [SD 1.8]; Study 2 mean 3.5 [SD 3.2]; t_{925}=−7.4; *P*<.001) and per week (Study 1 mean 12.8 [SD 13.5]; Study 2 mean 18.4 [SD 21.9]; t_{929}=−4.8; *P*<.001) than participants in Study 2. However, participants in Study 1 spent more days per week playing video games than participants in Study 2 (Study 1 mean 5.0 [SD 2.3]; Study 2 mean 4.7 [SD 2.2]; t_{717}=2.0; *P*=.046).

Video Game Behaviors by Positive Screen

Within each study, participants with any positive screen (PTSD, depression, AUD, or cannabis use) did not differ significantly from participants without any positive screen on video game behavior, while participants with either positive mental health screen (PTSD, depression) spent more hours per day and per week playing video games than those without a positive mental health screen (Multimedia Appendix 3). Pooling data across studies, participants with any positive screen for a mental health or substance use issue spent 2.61 more hours per week (95% CI 0.11-5.10) playing video games than participants without any positive screen. Participants with any positive mental health screen (PTSD, depression) spent 0.61 more hours per day (95% CI 0.30-0.92), 4.74 more hours per week (95% CI 2.54-6.94), and 0.41 more days per week (95% CI 0.13-0.70) playing video games.

Video Game Use by Services Receipt Among Participants With a Positive Screen

No association was found between video game use and either any services receipt, mental health services receipt, or substance use services receipt within both studies. Pooling data across studies, participants with any positive screen for a behavioral health issue who had received any type of behavioral health services (mental health services, substance use services) since discharge from active duty spent 2.67 more hours per week (95% CI 0.14-5.20) and 0.48 more days per week (95% CI 0.14-0.82) playing video games than participants with any positive screen who had not received any type of behavioral health services since discharge. Participants with any positive SUD screen who had received any type of substance use services

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since discharge spent 0.75 more days per week (95% CI 0.28-1.21) playing video games than participants with any positive SUD screen who had not received any type of substance use services since discharge.

Discussion

Principal Findings

We examined the video game playing behavior of two separate samples of young adult veterans recruited online. First, we found evidence across the two samples that most young veterans played video games: 54% of a general sample of young veterans and 74% of a sample of young adult veteran drinkers reported playing video games at least 1 hour per week. Next, among the video game players, we found that young adult veterans spent about 13-18 hours per week playing video games and about 2.5-3.5 hours per day playing video games. In a typical week, young adult veterans played video games on most days of the week. These findings suggest that video games might be a feasible intervention modality for young veterans generally and for behavioral health concerns specifically.

While most analyses did not yield differences that were replicated across both studies, we did find several replicated differences in video game behaviors among young adult veterans depending on their screening positive for a behavioral health issue as well as their receiving services for a behavioral health need. Regarding screening positive for a behavioral health issue, we identified the strongest evidence for more hours per day and per week playing video games among participants with a positive screen for both PTSD and depression compared with those without positive screens for these conditions. Regarding the receipt of services for a behavioral health need, we identified the strongest evidence that participants who had a positive SUD screen and received substance use services since discharge spent more days per week playing video games than those with a positive SUD screen who had not received substance use services.

Although most veterans in our sample played video games and those that did played quite often, our findings aimed to identify the potential groups of young adult veterans for the development and evaluation of video games as a modality for behavioral health services. Specifically, with respect to playing video games more per day and per week, young adult veterans screening positive for PTSD and depression may be more familiar with and dedicate more time to behavioral health services delivered via video games because these veterans already play more video games and more frequently than those without these issues and those not receiving services. For this population, relatively more intensive video game-based interventions might be acceptable. For example, previous research has demonstrated the feasibility of incorporating the core components of traditional cognitive behavioral therapies and exercise-based interventions for mental health into engaging, video games in Web-based, computer, console, and application-based formats [15-17,20,23,40,41]. Similarly, young adult veterans who have previously sought care but are currently not receiving services for SUDs are a more promising population than those with SUDs who have never sought care since their discharge from active duty. Because these veterans were open to receiving services in the past, video game-based interventions for this population could focus on delivering motivational interviewing techniques that encourage them to enter a new treatment episode [17,42] or be used to supplement care received after initiation to encourage retention and compliance with treatment goals (eg, completing cognitive behavioral therapy “homework” via video games).

Strengths and Limitations

Several strengths and limitations are worth noting. Strengths of this study include replicating analyses from two independent samples to reduce the rate of false positives [37,38]; sharing the data, code, and materials to facilitate computational reproducibility and verification (Multimedia Appendices 4 and 5) [43]; and signaling that these findings are exploratory [44] as they were not included in the study preregistrations [25]. In addition, using social media, we efficiently recruited hundreds of young adult veterans who currently play video games and screened positive for a behavioral health issue. We did this through Facebook advertisements that did not advertise the study to video game players exclusively. We did not mention in the ads that the study was looking for video game players, heavy drinkers, those with substance use or mental health problems, or those looking for treatment. Limitations include the exploratory nature of these analyses [45], recruiting our sample from Facebook, which limited the generalizability of our findings (though 10% learned about the study from family or friends and not directly from Facebook) [27] and the use of only self-report measures (ie, not diagnostic interviews) collected via the internet [25].

Future Work

Findings suggest several avenues of future research as well as collaborations between researchers and video game developers. First, analyses from this study would benefit from direct, preregistered replications to strengthen the credibility of our findings. Direct assessment of acceptability and willingness to engage with video games for behavioral health services should be incorporated into this research [16]. If our results are replicated, an empirically testable theoretical framework should be prospectively developed to provide more useful understandings of the relationships among video game use, behavioral health, and intervention than those provided by our entirely exploratory empirical analyses. Second, research is needed on the optimal types of video games (eg, role-playing, adventure, fantasy) for different young adult veteran populations [20]. Third, future research should investigate which types of behavioral health services can be best integrated into video games for different young adult veteran populations [17], with particular attention to young adult veterans facing health concerns not investigated in this manuscript yet likely in this population, such as physical pain and traumatic brain injury. Importantly, future research is needed to confirm that the number of hours spent playing traditional video games can be converted to engagement with games that address their behavioral health issues. Lastly, as video games are developed and implemented, rigorous evaluations are needed to assess the effects for specific behavioral health issues [22].

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Acknowledgments

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Conflicts of Interest

SG's spouse is a salaried-employee of Eli Lilly and Company and owns stock. SG has accompanied his spouse on company-sponsored travel. All other authors declare no conflicts of interest.

Multimedia Appendix 1

Codebook for Grant, Spears, and Pedersen (Study 1 and Study 2).

[PDF File (Adobe PDF File), 114KB - games_v6i3e15_app1.pdf]

Multimedia Appendix 2

Comparison of measures in Study 1 and Study 2.

[PDF File (Adobe PDF File), 30KB - games_v6i3e15_app2.pdf]

Multimedia Appendix 3

Exploratory replication analyses of video game use by young adult veterans.

[PDF File (Adobe PDF File), 30KB - games_v6i3e15_app3.pdf]

Multimedia Appendix 4

Markdown analytic code and output for exploratory analyses.

[PDF File (Adobe PDF File), 819KB - games_v6i3e15_app4.pdf]

Multimedia Appendix 5

De-identified dataset.

[XLSX File (Microsoft Excel File), 173KB - games_v6i3e15_app5.xlsx]

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Abbreviations

AUD: alcohol use disorder
AUDIT: Alcohol Use Disorders Identification Test
PTSD: posttraumatic stress disorder
RCT: randomized controlled trial
SUD: substance use disorder
VHA: Veterans Health Administration

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Original Paper

3MD for Chronic Conditions, a Model for Motivational mHealth Design: Embedded Case Study

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Abstract

Background: Chronic conditions are the leading cause of death in the world. Major improvements in acute care and diagnostics have created a tendency toward the chronification of formerly terminal conditions, requiring people with these conditions to learn how to self-manage. Mobile technologies hold promise as self-management tools due to their ubiquity and cost-effectiveness. The delivery of health-related services through mobile technologies (mobile health, mHealth) has grown exponentially in recent years. However, only a fraction of these solutions take into consideration the views of relevant stakeholders such as health care professionals or even patients. The use of behavioral change models (BCMs) has proven important in developing successful health solutions, yet engaging patients remains a challenge. There is a trend in mHealth solutions called gamification that attempts to use game elements to drive user behavior and increase engagement. As it stands, designers of mHealth solutions for behavioral change in chronic conditions have no clear way of deciding what factors are relevant to consider.

Objective: The goal of this work is to discover factors for the design of mHealth solutions for chronic patients using negotiations between medical knowledge, BCMs, and gamification.

Methods: This study uses an embedded case study research methodology consisting of 4 embedded units: 1) cross-sectional studies of mHealth applications; 2) statistical analysis of gamification presence; 3) focus groups and interviews to relevant stakeholders; and 4) research through design of an mHealth solution. The data obtained was thematically analyzed to create a conceptual model for the design of mHealth solutions.

Results: The Model for Motivational Mobile-health Design (3MD) for chronic conditions guides the design of condition-oriented gamified behavioral change mHealth solutions. The main components are (1) condition specific, which describe factors that need to be adjusted and adapted for each particular chronic condition; (2) motivation related, which are factors that address how to influence behaviors in an engaging manner; and (3) technology based, which are factors that are directly connected to the technical capabilities of mobile technologies. The 3MD also provides a series of high-level illustrative design questions for designers to use and consider during the design process.

Conclusions: This work addresses a recognized gap in research and practice, and proposes a unique model that could be of use in the generation of new solutions to help chronic patients.

(JMIR Serious Games 2018;6(3):e11631) doi:10.2196/11631

KEYWORDS

chronic conditions; consumer health informatics; gamification; health behavioral change; medical informatics; mHealth; user-centered design; information systems

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Introduction

Background

Chronic conditions are by far the leading cause of mortality in the world, representing more than 60% of all deaths [1] and taking more and more precedence over “traditional” acute illnesses. This is in part due to the increased average life expectancy [2] and major improvements in acute care and diagnostics that have created a tendency toward the chronification of formerly terminal conditions [3,4]. In these conditions, care is shifting to outpatient settings requiring people to learn how to manage on their own [5]. Chronic condition self-management refers to the ability of an individual, in conjunction with family, community, and health care professionals, to manage symptoms, treatments, lifestyle changes, and psychosocial and cultural consequences of health conditions [6]. Studies show that behavior patterns are among the main determinants of health, with actual health care services following far behind the individual’s social circumstances [7]. The fact that behavioral change is still a great barrier for patients is a recognized problem [8].

The field of consumer health informatics researches the role of information technology (IT) for health care consumers. Consumer health informatics is defined by Gunther Eysenbach as a field that “analyzes consumers’ needs for information, studies and implements methods of making information accessible to consumers, and models and integrates consumers’ preferences into medical information systems” [9]. Consumer health informatics can play a vital role for patient engagement and patient empowerment as it allows patients to take charge of their own health and their interactions with health professionals [10,11]. In this sense, mobile technologies hold promise because of their ubiquity, cost-effectiveness, less invasive nature, and their ability to provide immediate feedback and track activities [12-14]. By 2017, the global use of mobile phones had reached over 3.2 billion devices [15] allowing a variety of health interventions. The delivery of health-related services through mobile technologies and other wearable devices is called mHealth (mobile health) [16].

The use of mHealth mobile software apps has grown exponentially in recent years [17], with more than 100,000 apps available for download on online stores [18]. The world is currently seeing a surge of digital health start-ups [19] whose mHealth solutions usually fall into the general wellness, exercise, and diet category [20], neglecting condition-specific services. Only a fraction of these apps and services take into consideration the perspectives of relevant stakeholders, such as health care professionals and sometimes even patients themselves. To this purpose, a design philosophy called user-centered design (UCD) could prove useful because it places the needs and characteristics of intended users first and foremost [21-23]. In this manner, the goal of UCD is to create solutions specific to the user and the intended tasks [22,23]. Following UCD principles can generate systems that are easy to learn, have higher user acceptance and satisfaction, and lower user errors [22-24]. In addition, following good design principles early on not only can save time and money [25], but also decreases design changes late in the development process [24,26]. The use of UCD has been gaining traction in the design of health IT solutions, but it still is in its infancy.

A recent meta-analysis of behavioral change interventions showed that theory-based approaches have greater impact [27]. However, finding ways that engage patients to continue with an intervention is still a difficult task [28]. Additionally, in the past few years, more mHealth solutions have begun to use game elements to drive user behavior [29] in a practice known as *gamification* [30]. Game elements are incorporated into the greater context of the mobile app to bolster usability and compel continued and prolonged use [31,32]. However, gamification is not thoroughly understood yet. Despite the existence of some health gamification frameworks, a systematic review [33] found that as far as gamification design frameworks are concerned, the health sector is the least developed.

As it stands, designers of mHealth solutions for chronic conditions, who intend to create behavioral change interventions and integrate motivational elements, have no clear way of deciding what the relevant factors to consider are. This presents a relevant gap in knowledge that is yet to be answered appropriately in this field of study. The goal of this work is to address the lack of a model that allows the integration of motivational elements in the design mHealth solutions for chronic conditions.

Related Works

This section presents the theoretical background and scientific works related to this paper. Relevant medical concepts, behavioral change theories, and gamification considerations are described.

Chronic Conditions

Chronic conditions have a course that varies over time that is specific to the particular illness and can be very intrusive to everyday life. However, some common challenges across managing chronic conditions exist, such as recognizing symptoms and taking appropriate actions, handling complex treatment regimens, developing coping strategies, and dealing with frequent interactions with the health care system over time [34].

The context of this study (see Setting) provided the opportunity to work on two very different conditions: breast cancer and multiple sclerosis (MS).

Breast cancer is the most common cancer in women both in the developed and less developed world [1]. Thanks to advancements in treatments, breast cancer survivorship is on a steady rise and this cancer is no longer thought of as an acute illness but rather a chronic condition [3,4]. It is common to find mHealth solutions for breast cancer in the scientific literature such as tracking sleep patterns [35], symptoms and treatment side effect management [35-37], breast health and well-being assessments [38,39], and even comprehensive lifestyle programs with nutrition and physical activity elements [40].

MS is one of the world’s most common neurologic disorders [41]. The most common symptoms are overwhelming fatigue, visual disturbances, altered sensation, cognitive problems, and

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difficulties with mobility [42]. There have been recommendations that suggest the incorporation of standard MS management tools into mHealth solutions [43], and the scientific literature shows that some health apps do exist for fatigue assessment and fatigue management [44], emotional support [45], or self-management [46].

Behavioral Change

There are several theories and behavioral change models (BCMs) that are used in health behavior science with the main goal of making the healthy choice the easy choice.

The use of computerized health behavior interventions has expanded rapidly in the last decade and existing BCMs have been used to guide mHealth interventions: There is a growing body of evidence suggesting that mHealth can support health behavioral change in areas such as smoking cessation, physical activity, and other health care problems [47-51].

The use of instant feedback and positive reinforcement from learning theories are in common use in mHealth apps [29,47]. The Health Belief Model has been used in mHealth interventions for self-management and health promotion [52-54], the Transtheoretical Model has been used in mobile solutions for smoking cessation and other addictive behaviors [55-58], and physical activity and fitness interventions use the theory of planned behavior [29,50,59] as well as self-regulation theories [29,60-63]. The basis for social cognitive theories can be found in many interventions using health apps for disease management [64-66] and goal setting is very often used in mHealth apps [60,67]. It has been noted that each BCM carries its limitations and problems [68-70]. A multitheory approach is usually recommended in behavioral change intervention design [71] and this should be considered when designing mHealth solutions.

Mobile devices have the capacity to interact with the individual with much greater frequency and in the context of the behavior [72]. mHealth interventions allow for tailoring not only during the beginning of an intervention process, but also during the course of intervention [73]. As such, these mobile technologies are “always on” and are carried on the person throughout the day, offering more chances for interaction and intervention [17]. Therefore, mHealth interventions for behavioral change would benefit from contemplating the dynamic nature that mobile capabilities have to offer: rapid intervention adaptation based on the individual’s current and past behavior and situational context [17]. A behavior change support system (BCSS) is a sociotechnical information system with psychological and behavioral outcomes designed to form, alter, or reinforce attitudes, behaviors, or an act of complying without using coercion or deception [48]. The creation of BCSS involves a variety of disciplines from human sciences to information systems.

There are BCSS design models such as the Persuasive Systems Design (PSD) [74], which concerns the design of persuasive technologies in general. In this model, the need for recognizing the intent of persuasion, understanding the persuasion event, and defining and/or recognizing the strategies in use are key. Another BCSS design model is the IDEAS (Integrate, Design, Assess, and Share) framework [75]. In this model, behavioral change theory and design thinking are integrated to guide the development of digital health interventions. The Chronic Disease mHealth App Intervention Design Framework [76] is specific to mHealth and it focuses on chronic conditions, addressing issues present in the other frameworks. The issue of enjoying doing the behavior, however, is not addressed in these models.

Gamification

It is not surprising that efforts to translate the feeling of engagement and enjoyment that games have to other areas of our life have been attempted. Gamification is generally understood as the use of game elements in nongame contexts [30] and its use can be seen as one form of persuasive or motivational design [77].

In this work, the terms *gamification design* and *gameful design* are used interchangeably, since they frame the same extension of phenomena through different intentional properties [78].

Gamification Elements

Game elements are varied, but usually the literature on game design considers the following to be the basic set [78-80]:

1. Points and leveling systems, which provide feedback and inform the user of their level of familiarity of the system.
2. Leaderboards that are used to dynamically rank individual user progress and achievements as compared to their peers.
3. Badges, achievements, and trophies, which act as rewards for the accomplishment of specific tasks.
4. Challenges and quests that constitute objectives and create a narrative within the system.
5. Social features are used to support and reinforce interaction between users.

Each of these elements by themselves are not seen as “gameful” [78], but combined and arranged in certain ways, they can tap into something greater and unlock a unique experience. In the context of mobile apps, these elements are integrated as specific features for purposes of bolstering usability and compelling continued use [31,32].

Users and Player Types

As with BCMs, the literature suggests that the different user or player types will have different needs and it could be useful to keep them in mind during the design process. Asking gamers why they play videogames shows that there is no single and unified answer [81].

There have been many attempts to create “player types” for design and analysis purposes. Game designer Richard Bartle observed the way users of an online game behaved and wrote down his observations creating what is now known as Bartle’s taxonomy [82]. However, Bartle’s taxonomy was never intended to be a general typology, only a description of his observations in one particular context [83]. Others have tried to address this problem, such as Yee [84] with his empirical model of player motivations, or Marczewski [85] who developed the Gamification User Types Hexad framework using self-determination theory as the theoretical background and research on human motivation, player types, and practical design

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experience. According to Marczewski, user types are segmented and supported in the following ways:

1. Philanthropists are individuals motivated by altruistic purposes, willing to give without expecting a reward within the system.
2. Socializers want to interact with others and create social connections. The system is important to them but as a means to connect.
3. Free Spirits desire the freedom to express themselves and act without external control. They like to create and explore within a system.
4. Achievers seek to progress their status by completing tasks or prove themselves by tackling difficult challenges. The system is a challenge to be overcome.
5. Players are motivated by extrinsic rewards. The specific type of reward is not important, only that the system is providing it.
6. Disruptors enjoy testing the limits of the system, looking to push past them. Sometimes they can be negative agents, sometimes their work improves the system.

Gameful Design Models

Gameful design is about intentionally designing for gamefulness in the development of nongame environments using game design thinking [78]. Simply inserting the different game elements into any nongame context is not sufficient—the tasks themselves have to be designed in a manner similar to game design [86]. In this sense, game design should be approached as a lens to improve the overall experience of the task.

There are models for game design such as the Mechanics, Dynamics and Aesthetics framework [87] that aim to help game designers. Designers have used this kind of game design model before [33] to gamify activities, but it is clear that the process of gameful design is somewhat different from game design. Games are mostly directed toward pure entertainment, whereas gamification attempts to enhance engagement and user experience in different contexts [88]. The design approach of a gameful system is different than that of a conventional game.

The gamification framework of the Werbach and Hunter [89] gamification framework, commonly known as 6D, is one of the most popular and referenced gamification design frameworks, created with the purpose of designing a service or product with business goals. Another commonly used framework is called Octalysis [90]. In this framework, the design process is viewed from a "human-focused" lens as opposed to "function-focused" points of view. The authors propose that design processes concentrate normally on optimizing efficiency, getting the job done, rather than on human motivation.

Even if these gamification models exist, it is important to keep in mind that one cannot expect that they perfectly translate to health scenarios. In generic gamification models, the goal is usually to increase a certain task efficiency or improve user retention [33]. Although these may look appropriate on a surface level, there are hidden dangers inherent to health care. Generic gamification models often do not contemplate potential negative consequences. Ethics should guide the design of health technologies and recognized principles of bioethics play an important role in this process [91]. Because of these issues, specific conceptual frameworks for gamification in health are being developed.

The Wheel of Sukr is a health-specific gamification framework for assisting diabetic patients to self-manage and reinforce positive behaviors [92]. The Wheel of Sukr framework uses reward systems to motivate users toward healthy behaviors. Its theoretical basis lies in reaching the state of flow and motivation as understood by self-determination theory. Another health-oriented gamification framework is PACT (People, Aesthetics, Context, and Technology) [93], a participatory design framework for the gamification of rehabilitation systems that looks to involve all the relevant stakeholders from the beginning of a rehabilitation design process. This framework, however, does not use any behavioral change theory as foundation.

Despite the existence of some health gamification frameworks, a systematic review [33] found that as far as gamification design frameworks are concerned, the health sector is the least developed.

Methods

Study Design

Consumer health informatics is a complex phenomenon and the study of such phenomena can often improve with the use of methodological triangulation to generate more thorough results [94,95]. The combination of different research methods tends to decrease the weaknesses of an individual method and strengthen the outcome of the study. This work uses an embedded case study methodology to research the design of mHealth solutions.

An embedded case study is a case study containing more than one subunit of analysis [96]. The embedded case study methodology provides the means of integrating quantitative and qualitative methods into a single research study [97]. Embedded case studies explore the phenomena in terms of subunits, each focusing on different features. The data obtained from the cases are interpreted in a transformational process that relies on different methods to arrive at a perception, judgment, or evaluation [97]. In this way, a synthesis is created, resulting in new knowledge.

Setting

This work is the result of an industrial PhD experience that took place in Salumedia Tecnologias, a digital health company in Spain, over the span of 3 years as part of a Marie Skłodowska-Curie research fellowship (see Acknowledgments).

Study Case

To explore design factors for mHealth solutions for chronic patients, different disease courses, management, and symptomatology had to be taken into consideration. Two very different chronic conditions were selected because they represent different models of chronic conditions and provide a rich area of analysis that is useful to prevent the results from being overly specific to one condition paradigm. MS represents a chronic condition that manifests itself in the life of a patient as they

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become young adults [41], whereas breast cancer represents an acute condition that becomes chronic thanks to improved treatments and care [3,4].

The way embedded case study methodology was used in this research was through a single embedded case with four embedded units as illustrated in Figure 1. The dashed lines represent the blurred boundary between a case and its context.

The design of mHealth solutions within Salumedia was used as an instrumental case study. Instrumental case studies differ in that the case itself is secondary to gaining understanding on a particular phenomenon [98]. What each embedded unit was and how it was explored is detailed in the following sections.

Data Collection

The embedded units used different quantitative and qualitative methods which are described subsequently.

Embedded Unit 1: Breast Cancer and Multiple Sclerosis mHealth Apps Review

To understand the current landscape for mHealth solutions for the selected chronic conditions, two cross-sectional studies [99] were undertaken: one for breast cancer [100] and one for MS [101].

Selection criteria that would allow identification and classification of all relevant apps was designed and each app was systematically explored. Almost 600 breast cancer apps and 25 MS apps were categorized by their intended purpose, the reliability of their contents, their intended audiences, and the institutions behind each app.

There was a clear difference between MS and breast cancer apps not only in features, but also in other aspects such as their intended audiences. These studies provided insight regarding the state of the practice of mHealth solutions for chronic conditions and the features and characteristics that available health apps offer.

Embedded Unit 2: Gamification Presence in mHealth Apps

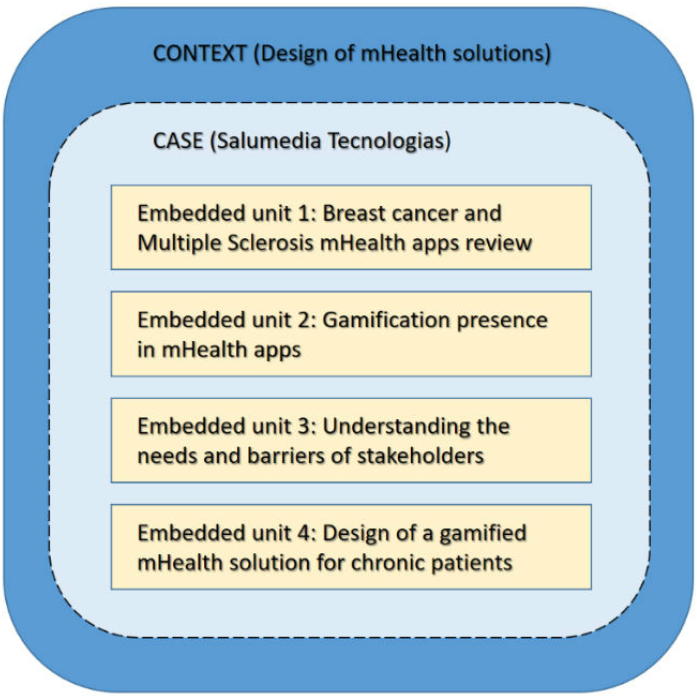
Gamification was present in the apps from the previous embedded unit, so the study of the phenomena continued. The larger number of breast cancer apps allowed for richer exploration.

Based on the scientific literature on gamification and game elements, and with the help of a panel of experts, we were able to generate a catalog of gamification concepts and constructs. In another study [102], we empirically studied the presence of gamification in breast cancer apps and developed a predictive model to automatically detect the presence of gamification in large samples of breast cancer health apps using only the title and description text of the app. The steps involved in the construction of this gamification screening tool nurtured the understanding of gamification techniques and how they can be applied in the design of health apps.

Embedded Unit 3: Understanding the Needs and Barriers of Stakeholders in Chronic Conditions

To see how UCD could be applied to the design of behavioral change mHealth solutions, we conducted a mixed methods design study with qualitative and quantitative components to explore the views of chronic patients and the health care professionals who work with them [103].

Figure 1. Embedded case study used in this research. The dashed lines represent the blurred boundary between a case and its context.



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The qualitative part consisted of focus groups and interviews of persons with MS and health care professionals; the quantitative part consisted of structured surveys and standardized tools such as a satisfaction with life scale [104] and electronic health (eHealth) literacy scales [105]. Participants in this study were coded as "PWMS" for persons with MS and "HP" for health care professionals ranging from 1 to 12 (eg, PWMS11 or HP02).

The work in this study was used to inform on the design factors specific to living with and managing chronic conditions, as well as the care process involved.

Embedded Unit 4: Design of a Gamified mHealth Solution for Chronic Patients

Research through design is a methodology that employs methods and processes from design practice as a legitimate method of evidence [106]. In this method, design activities play a formative role in the generation of knowledge.

Building on the insight and knowledge gained from the previous embedded units and the available scientific literature, we used a research through research to design a mHealth solution called More Stamina [107]. More Stamina is a gamified fatigue management app for persons with MS. Because More Stamina attempts to create a health behavioral change, relevant models and theories were explored and understood for their use.

The design process for More Stamina required deep exploration of both BCMs and the use of gameful design. The interplay between these two areas of knowledge and the users' needs were key during requirement negotiations that shaped the final design. The work involved in this research was valuable to the understanding of factors for mHealth design for chronic conditions.

Data Analysis

A broad range of analysis methods were used on the collected data from both the quantitative and qualitative approaches.

Embedded Unit 1: Breast Cancer and Multiple Sclerosis mHealth Apps Review

The work in embedded unit 1 used a descriptive quantitative study approach to show the composition of the mHealth solutions ecosystem and what kind of tools and features are available for persons with the selected chronic conditions. For each individual study, two reviewers independently reviewed app information using structured forms and going over the app store descriptions to classify and categorize each app. Fleiss-Cohen's coefficient was used to assess interrater reliability according to Landis and Koch's standards [108].

Embedded Unit 2: Gamification Presence in mHealth Apps

In embedded unit 2, the process of creating the gamification detection algorithm used multivariate logistic regression where significant and relevant variables were incorporated into the algorithm. The reliability of the algorithm was evaluated using receiver operating characteristic (ROC) curves for the predicted values of gamification presence. Several iterations of the logistic model were compared to each other using Akaike's information criterion (AIC) [109] and the one with the largest area under the ROC curve and the lowest AIC was selected.

Embedded Unit 3: Understanding the Needs and Barriers of Stakeholders in Chronic Conditions

Embedded unit 3 used two methods simultaneously: a qualitative exploration of the different stakeholders in a chronic condition and standardized structured questionnaires to complement each other. The focus groups and interviews in the qualitative part were audio-recorded, transcribed verbatim, and coded using the qualitative data analysis management program NVivo 11 (QSR International, Melbourne, Australia). The transcripts were independently analyzed first and then jointly during meetings to consolidate concepts. Recurring themes and subthemes were identified and coded during a deductive phase; thematic analysis was performed during an inductive phase [110]. The results of the quantitative standardized structured questionnaires were analyzed according to their own evaluation matrices.

Embedded Unit 4: Design of a Gamified mHealth Solution for Chronic Patients

The embedded unit 4 used design practice as a way of generating knowledge in an iterative and reflective manner through the practice of hands-on design work. The findings from embedded unit 3 were used as user requirements; BCMs and gamification concepts were considered during requirement negotiations. We used Nielsen's heuristics [111] as design guidelines and evaluation methods for the usability of the resulting prototype. The evaluator team independently examined each heuristic for all prototype screens. Notes were taken on major and minor issues discovered to be later contrasted among them. After each heuristic evaluation, the prototype was modified and assessed again. This process was iterated until all usability issues were deemed to be addressed.

Overall Analysis

The data obtained from the different embedded units and relevant related research were then gathered for analysis. The objective of this analysis was to generate an abstraction of concepts that could be extrapolated and extracted into a series of high-level illustrative design questions. The collection of design questions was then subject to a thematic content analysis [110] in which recurring themes and subthemes were sought. This followed an inductive approach in which the themes identified were data driven. The exploration and definition of themes and subthemes focused on aspects that would be relevant in finding out how to design mHealth solutions for persons with chronic conditions, which would be valuable and meaningful for all stakeholders in the health care context and could fulfill the needs of the stakeholders. Aspects that are obvious for any information and communications technology-based solution were not incorporated; for example, the fact that the solution should be error free, that it should follow relevant laws and regulations, that cost should be within the designer's limitations, and so on.

To help ensure the integrity of the content analyses, the guidelines set by Shenton [112] were followed, which include collecting and analyzing data in an iterative process to identify themes and generating an audit trail among others. The use of

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methodological triangulation allowed complementary findings to converge creating greater understanding from different parts of the different concepts.

The iterative process of grouping and subgrouping illustrative design questions led to a series of abstract constructs that were used to create a model that can be useful to guide the design process of condition-oriented gamified behavioral change mHealth solutions.

Ethical Considerations

The ethical approval for studies involving participants was obtained from the Swiss Ethics Committee on Research Involving Humans (ID #2016-00529). The participants were informed about the nature of the research project; the reasons for their subjectability; risks, benefits, and alternatives associated with the research; and their rights as research subjects before agreeing to participate. Steps were taken to ensure that data gathered from participants were kept under strict security, anonymity, and privacy.

Results

A Model for Motivational mHealth Design: 3MD for Chronic Conditions

Overview

The embedded units were used to extract valuable insight for the study case. Data from the different embedded units and scientific literature was integrated and is presented in the subsequent sections to provide traceability and facilitate the thematic trail. As a result of the thematic analysis, design factors emerged from the data and are grouped in the form of the components for the conceptual model called "Model for Motivational Mobile-health Design (3MD) for Chronic Conditions." A conceptual model is a high-level description of how a system is organized and operates [113]. According to Storrs [114], models are "frameworks for understanding" a subject; they are representations that are used to help people know, understand, or simulate a subject the model represents.

The main components of the 3MD for Chronic Conditions are condition specific, motivation related, and technology based (see Figure 2). A general overview of the model is presented in Textbox 1.

The 3MD is aimed at designers of mHealth solutions and because of this and the fact that the ecosystem largely consists of start-ups and individual entrepreneurs, the overall language and approach was chosen. The model proposes illustrative design questions expressed in layman's terms, minimizing academic terminology. These questions are not definitive ones; rather, they work as a means to illustrate how to approach each component to guide the design process. Designers are encouraged to explore and expand them, creating more subsets that fit their purposes. A description of each component and their respective factors can be found in the following subsections along with their respective series of illustrative design questions.

Condition Specific

Although chronic conditions share similar overall needs, each condition has inherent differences and idiosyncrasies. These differences require special fine tuning during design. In embedded unit 3 and embedded unit 4, the relevance of centering the design of mHealth solutions around identified patient needs and characteristics was highlighted.

The condition-specific component describes factors that need to be adjusted and adapted for the chronic condition in question. Further thematic analysis grouped these factors into subgroups: common condition problems, patient self-narrative, and care process.

Common Condition Problems

Persons with chronic conditions are affected by a myriad of problems that alter the way they live their lives. Some conditions require patients to spend a significant amount of time dealing with their symptoms and disease management, but these are not the only issues that ail them. The work on embedded unit 3 showed how persons with chronic conditions can be concerned or even afraid of issues that the health care team may disregard. Such was the case where one health care professional claimed:

> *If you ask them "how do you feel," they will always say "I don't feel good." Interestingly, this feeling doesn't change, they may train over three, four, or five weeks and they will feel the same. However, if you look at the parameters that you normally assess, you will see that they have improved. VO2, oxygen uptake, or maximum heart rate will have gone up. They objectively improve, but subjectively still feel bad. 2, oxygen uptake, or maximum heart rate will have gone up. They objectively improve, but subjectively still feel bad.* [HP11]

In this example, one can see that the subjective experiences of persons with MS were placed in an inferior condition than the "objective" physiological parameters.

Chronic conditions have symptoms that affect patients physically, emotionally, and even cognitively. Figure 3 shows some of the findings of the embedded unit 1 in which disease management (symptom management) and disease information were greatly represented among the available mHealth solutions.

There are lifestyle changes that persons with chronic conditions adopt that can cause sometimes even more resistance and problems than simple medication adherence. In embedded unit 3, MS conditioned the way persons with MS lived their life, seeing their physical energy as a resource that needs to be managed and in many other subtler ways. Simple weather conditions such as warmer temperatures worsened MS symptoms according to some of the interviewees. In some cases, chronic conditions can diminish their sense of self-efficacy; PWMS02 claimed that there are times when "you don't know how much confidence to have in yourself."

Having a social circle of family and friends who provide support was a determining factor for motivating persons with chronic conditions in embedded unit 3. Friends and family reminded

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them that "We're not alone with our MS. There are people thinking about what they can do to help us" (PWMS08).

The way others who were not part of the close social circle behaved and reacted also determined their actions. Designers would benefit from understanding how patients deal with these changes and how it affects them as human beings.

The illustrative design questions for this section and their audit trail summary are presented in Textbox 2.

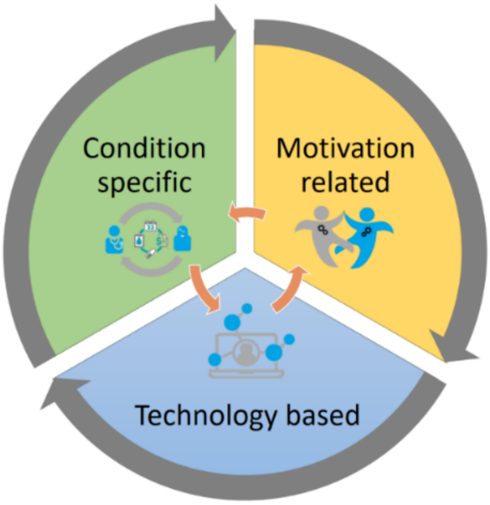
Patient Self-Narrative

The way the particular condition manifests itself in the life of the patient changes greatly how they relate to it. A person living with a condition since childhood is more likely to see it as part of themselves as opposed to thinking it is something that happened to them. Additionally, the way in which the condition manifested also plays a role, as receiving the diagnosis due to an emergency situation or routine testing changes perspectives and expectations.

In embedded unit 3, health care professionals and persons with MS commented on the different strategies that the chronic condition forced patients to undergo to appear "normal." For example, one patient referred to strategies to cover up symptoms from others:

> *I use one trick, I move all my appointments to the morning so people around me don't realize that I'm not well. I then take a break in the afternoon and if someone wants to do something, I just say that my calendar will free up again in the evening.* [PWMS02]

Figure 2. Interaction of the 3MD (Model for Motivational Mobile-health Design) components.



Textbox 1. Model component overview of the 3MD for Chronic Conditions.

1. **Condition specific**

   Factors that act as the foundation of the design process because they provide direct and indirect knowledge about intended users, relevant stakeholders, and their characteristics.

   - Common condition problems
   - Patient self-narrative
   - Care process

2. **Motivation related**

   Factors that nourish our understanding in regard to the type of intervention and experience we are building.

   - Behavioral change aspects
   - Gameful aspects

3. **Technology based**

   The different technological factors that can be used to mold and craft the particular mHealth solution.

   - Quantification
   - Tailoring
   - Representation

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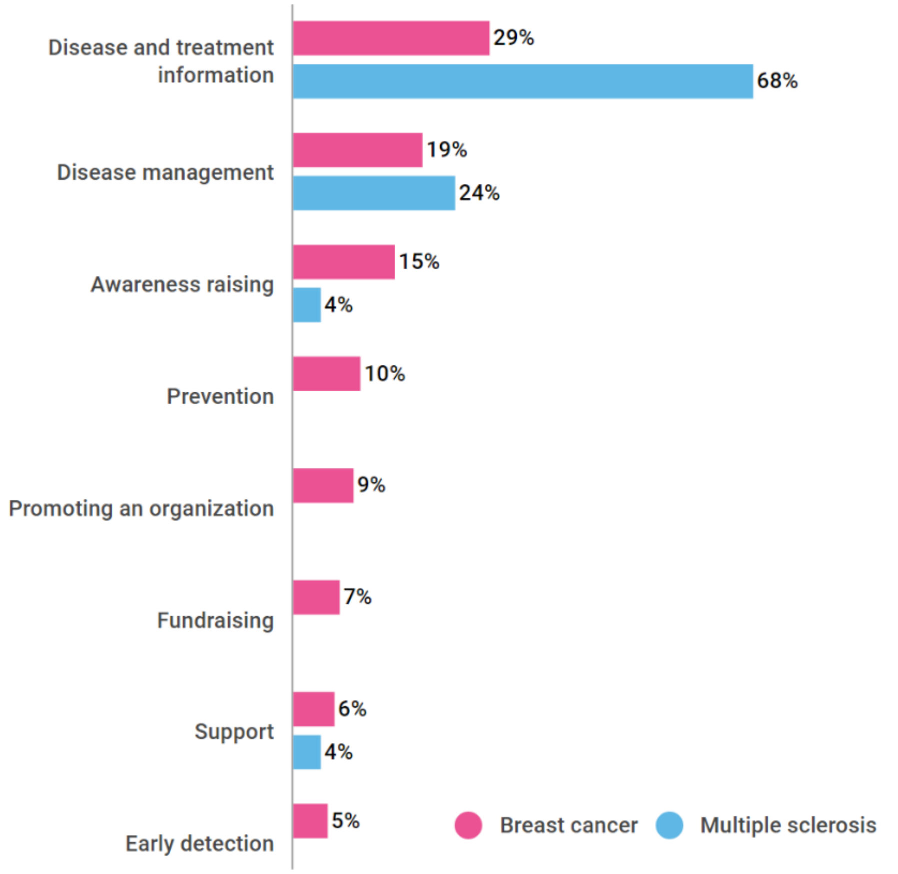
Figure 3. mHealth app features found in embedded unit 1 for breast cancer (n=599) and multiple sclerosis (n=25).



Textbox 2. Common condition problems illustrative questions.

Symptom and treatment related (embedded units 1 and 3)

- What does the medical literature say are the main symptoms of the condition?
- What kind of treatment are people with the condition receiving?
- What are common side effects for these treatments?
- What do people with the condition feel about their treatments?
- How much do people with the condition feel they understand their condition?

Condition-driven lifestyle changes (embedded units 1 and 3)

- How much has the lives of people with the condition changed because of the condition?
- What kind of things does a person with the condition “have to do” now?
- How has routine been disrupted for those with the condition?
- What strategies have people with the condition developed to cope?
- How can our design make people with the condition feel more in control?

Social impact (embedded units 1 and 3)

- How has the condition changed the way people with the condition relate to others?
- Are there things that someone with the condition feels they have to hide?
- How are the individual and social circle adapting to the changes brought on by the condition?
- In what way are people with the condition involving others in condition-related issues?
- Has living with the condition affected the relationship with significant others?

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The concept of “normalcy” was very important to persons with chronic conditions. Some conditions require almost constant care; the level of disruption to normal life determines the burden of the condition. The health care professionals in embedded unit 3 often recommended understanding the emotional and psychological mindsets that the special circumstances of living with a particular chronic condition places on patients.

Another aspect to consider is what views the larger society and culture hold toward the condition in particular. A special kind of health app was present in embedded unit 1: those for raising condition awareness. Some diseases have different status within the collective mind. People with cancer are a good example: as they get better, they become survivors and command a certain level of respect because they have “beaten” the condition. However, not all cancers are treated the same way. Although breast cancer—perhaps due to awareness campaigns or the target population—is perceived as something that “happens to” women, lung cancer—due to its association with tobacco and smoking—is seen as something that the individuals “brought on themselves.”

The illustrative design questions for this section and their audit trail summary are presented in Textbox 3.

Care Process

The findings from embedded unit 3 were also in line with the idea that designers of mHealth solutions should acknowledge the place the intervention will have within the accepted care flow. Health care is a team effort, each stakeholder is a member with a special role to play. Chronic conditions present scenarios that require joint collaboration from many disciplines and agents, which increases the complexity and the number of stakeholders involved. The absence of health care professionals’ involvement in health app development was evident in embedded unit 1 as well as recognized in the literature.

Each and every stakeholder carries their own agenda, their own goals, and expectations and it is important to keep this in mind or the health care team can become a barrier for mHealth solutions as seen in embedded unit 3:

> *It’s maybe true that we [health care professionals] are not likely to recommend or suggest technology-based solutions. I never thought about it. Maybe because there is still no clear answer as to how apps can help. Perhaps we feel that the personal relationship that we form with our patients is not something we can replace with technology.* [HP05]

The illustrative design questions for this section and their audit trail summary are presented in Textbox 4.

Motivation Related

Motivation derives from the French word “motivé,” which points to the concept of needs, desires, wants, or drives that we as humans may have. The design of a behavioral change mHealth intervention aims to create a solution that can motivate people to enact our intended action.

The motivation-related component describes factors that address how to influence behaviors in an engaging manner. As a result of thematic analysis, these factors were clustered as behavioral change aspects and gameful aspects.

Textbox 3. Patient self-narrative illustrative questions.

Sociocultural perspectives (embedded units 1 and 3)

- How is the condition perceived by society?
- Do people with the condition carry any social stigma?
- How is society working to help people with this condition?
- How much condition awareness exists in society?
- Are there special accommodations required for people with the condition?

Living with the condition (embedded units 3 and 4)

- At what age is the condition usually diagnosed?
- How does the condition manifest for the first time?
- Do the condition and treatment regimens change over time?
- Are there different phases or stages to the condition?
- How long has the target population been living with the condition?

Condition burden (embedded units 3 and 4)

- How much time per day does someone with the condition have to invest in symptom management?
- Do people with the condition have other chronic conditions to manage as well?
- How much skill does disease management require?
- Are there things that someone with the condition could do before and now they cannot do anymore? How do they feel about these changes?
- In what ways do people with the condition feel that the condition disrupts their normal life?

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Textbox 4. Care process illustrative questions.

Health care team composition (embedded unit 3)

- What kind of health care professionals are involved in the treatment of this condition?
- Who is the health care professional responsible for the overall treatment?
- How are other professionals brought into the process?
- Are there nonmedical professionals involved?
- What is the involvement of informal caregivers?

Stakeholder dynamics (embedded units 1 and 3)

- What is the role of each stakeholder in the process?
- How do health care professionals relate with one another?
- Do health care professionals feel that there is an overlap in activities?
- What do informal caregivers think of the care process?
- How is the care process established?

Health care system use (embedded unit 3)

- How often do people with this condition need to interact with the health care system? How long are these interactions?
- What are the different steps required for each interaction with the health care system?
- Are visits to the emergency room an expected occurrence for people with the condition?
- Do medical interventions require rehabilitation periods?
- Are surgical interventions required?

Behavioral Change Aspects

Depending on the objective of our intervention, it is likely that our behavioral change approach will be different. The scale of the intervention is as important as whether we are creating a new behavior or reinforcing an existing one. Not all interventions carry the same expectations in regards to the duration of their effects. A person with MS may need continuous reinforcing of his determination to do rehabilitation exercises, whereas a breast cancer survivor who needed to deal with chemotherapy side effects does not. Some behavioral change interventions may have specific goals for specific moments in time or do not expect that the behavior remains after a certain period.

The related research on behavioral change states that single theory approaches are not recommended. A certain level of requirement negotiations between existing BCMs and our mHealth solution is necessary. In the embedded unit 4, BCMs were key during design negotiations. Each design concept was deconstructed to find matches with current behavioral change models; when a specific part of a BCM was not addressed by a design concept, the concept was explored further until integration with the behavioral change models felt natural or the concept was discarded. To facilitate this process, an ad hoc diagram representing the constructs from the BCMs we considered was created in embedded unit 4 (see Figure 4).

Behavioral change factors demand careful thought during the design phases to understand which behavioral change model or models to select and combine. The illustrative design questions for this section and their audit trail summary are presented in Textbox 5.

Gameful Aspects

The need for a more enjoyable experience was present in embedded unit 3. Game-like features were desired by persons with MS such as PWMS02 who expressed:

> *[an app could present something like] an obstacle course that you have to get through. [Something] that you tackle daily. The app would have to give you an alert that says you have to walk 2 km today, for example. And you have to be able to set [your own] goals. The patient should try how long he or she can walk and then perhaps increase the amount. That would maybe make people use it more. In a game, there are also tasks that you have to do. If you finish them, you get something.* [PWMS02]

This game-like attitude heavily resonated in several other persons with MS and even some health care professionals:

> *For me, it's important that (the app) is playful. We all remain children deep down. It should have colors, some music, and be attractive.* [HP03]

The findings in embedded unit 1 and embedded unit 2 tell us that the trend of gamification in health apps is strong. From the related research on gamification, we understand that the creation of a gamified system is synonymous to crafting an experience that attempts to transport users to a different, more playful mindset.

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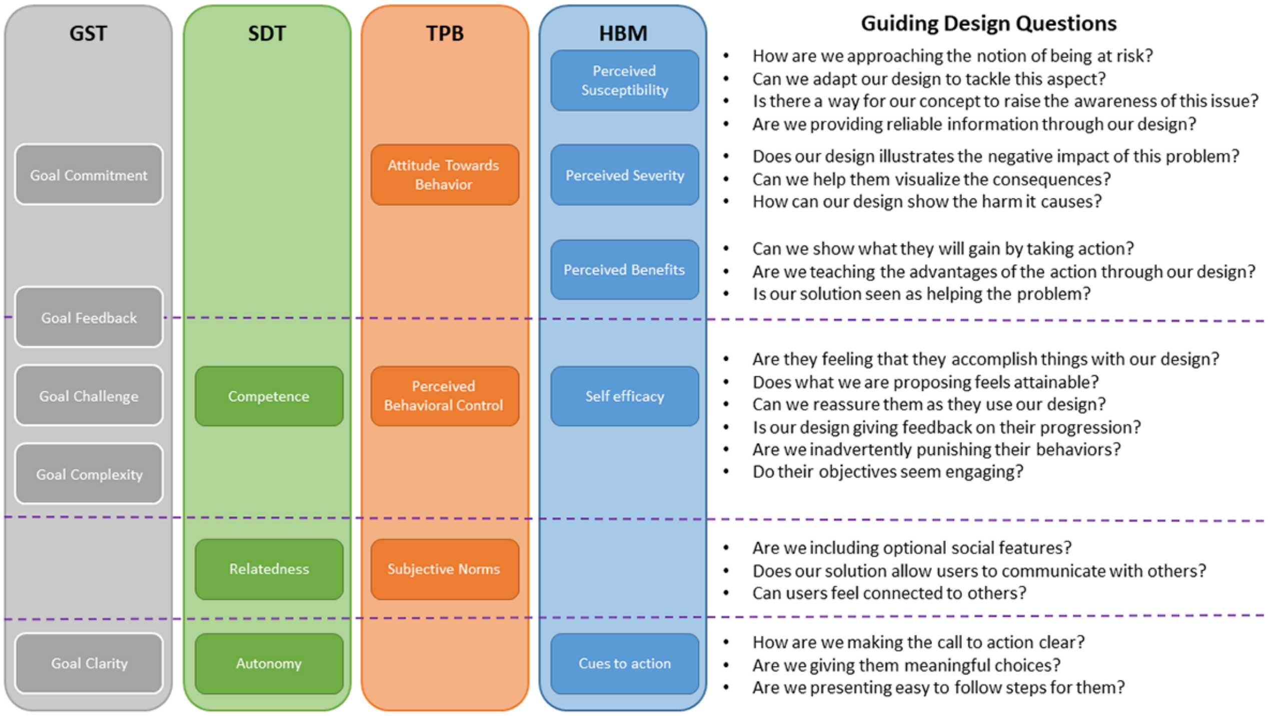
Figure 4. Behavioral change model requirement negotiation diagram from embedded unit 4. GST: goal-setting theory; HBM: Health Belief Model; SDT: self-determination theory; TPB: theory of planned behavior.



Textbox 5. Behavioral change aspects illustrative questions.

Type of behavior (embedded units 1 and 4)

- What kind of behavior change are we as designers trying to achieve?
- What models have been successfully used for this condition before?
- Is the behavior an existing behavior or a new one?
- Does the condition go through stages?
- Is our intended intervention ethical?

Behavior over time (embedded unit 4)

- How complex is the behavior that our intervention is trying to establish?
- Can the intended behavior be broken down into smaller or shorter behavioral components?
- What is the estimated duration of the intended behavioral change?
- What evidence is available for the intended behavior change?

Intervention scale (embedded unit 4)

- What is the size of our intended population?
- Are there models that fit the size of our intervention better?
- Are there proven ways to reach our target audience?
- How are we measuring the effectiveness of our intervention?
- Which are the most cost-effective ways for the size of our intervention?

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Textbox 6. Gameful aspects illustrative questions.

Experience style (embedded units 1, 3, and 4)

- What opportunities are we as designers offering for socialization?
- Does our design provide challenging opportunities for our intended users?
- Does our experience or intervention benefit from having a narrative?
- How are we as designers providing our intended users with clear objectives?
- How rich and complex is the game world of our design?

Immersion density (embedded unit 4)

- How deep of a gameful experience does our intervention requires?
- Are there metaphors that can help tell a story within our design?
- How does our gameful system fit our intended target population?
- Is the tone of our message coherent with our design?

Element selection (embedded units 2 and 4)

- What kind of game elements can we as designers use for this design?
- Which elements seem appropriate for the type of experience that we as designers are building?
- Are virtual self-representations needed in our design?
- How can we as designers transmit the feeling of progress?
- Is social comparison useful to our design?

From the work done in embedded unit 4, it became clear that the use different types and layers of gamefulness needed to be adjusted for our particular intervention. The task of constructing a gameful experience requires that we acknowledge that not all systems require or even benefit from the same features or elements. In embedded unit 3, participants commented on the advantages of social interaction among peers, but the idea of competing with each other was not appreciated:

> *It's important to distinguish how you're connected. I don't want to compete [with other persons with MS].* [PWMS07]

A more immersive system might make a symptom management app take the form of monsters invading us unless we warn them off through "rituals of prevention" that cast them off, whereas a less immersive system might only require that we check the tasks as done.

The illustrative design questions for this section and their audit trail summary are presented in Textbox 6.

Technology Based

Mobile technologies offer a wide variety of features that can be used to help chronic patients improve their quality of life and manage their condition. Technology should work together with the condition-specific needs and engagement aspects to find a solution that fully benefits all stakeholders. In embedded unit 4, we centered the design of a mHealth solution on the intended users, following personas that we created in embedded unit 3 as user representations.

The design features for mHealth solutions for persons with MS found in embedded unit 3 are:

1. Customizable goal setting: challenges need to be tailored to the specific person with MS characteristics.
2. Energy profiles and fatigue management: information and tools that help users in managing their day-to-day activities.
3. Patient education: offer verified information that is helpful and reliable.
4. Data visualization: information must be presented in a way that is meaningful to persons with MS.
5. Positive feedback system: rewards and incentives for completing tasks and objectives.
6. Activity tracking: register metrics such as distance walked or run, calorie consumption, heart rate, and quality of sleep among others.
7. Exercise library: a collection of different activities beneficial to persons with MS such as fitness or relaxation techniques that can be selected.
8. Game-like attitude: playfulness is a mindset whereby people approach activities as something not serious, in a way that is highly pleasurable and motivating.
9. Strong evidence base: features and information offered should have a solid scientific foundation.
10. Remote monitoring: health care providers can follow persons with MS progress and give feedback.
11. Optional sociability: ability to opt-out of social media features such as messaging, feeds, and/or other kinds of social comparisons.
12. Reminders system: notifications that remind persons with MS to engage in activities.
13. Personal data management: access to personal information and data defined by the user case by case.

The technology-based component describes factors that are directly connected to the technical capabilities that mobile

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technologies offer that could be used in behavioral change mHealth interventions. Using thematic analysis, these factors were subgrouped as quantification, tailoring, and representation.

Quantification

By giving a clear numerical value to an event or activity, we are providing an objective reference point that is useful for us to make decisions. Related research on chronic conditions speaks highly of different variable tracking during the course of a disease. This was in line with the findings of embedded unit 1, where a large percentage of health apps dealt with disease management.

Gathering data can help empower people with chronic conditions and allow them to take more control over their lives; the need for this design feature was mentioned previously. The mHealth tool called More Stamina we designed in embedded unit 4 had the purpose of tracking and monitoring fatigue in persons with MS. mHealth solutions can propose systems that provide information for decision making and feedback on how they are doing and what to do. With the right tools and the right data as input, figuring out the next move for our intended users is more accessible.

The illustrative design questions for this section and their audit trail summary are presented in Textbox 7.

Tailoring

The majority of mobile phones are sold with embedded accelerometers, gyroscopes, and GPS chips. It is because of these features and how we use them that where we have been and things such as how often we really go to the gym can be known. There is probably more data about our lives in our mobile phones than there is in our houses. However, not everyone relates to their mobile devices in the same way. The degree to which people obtain, communicate, process, understand, and deal with electronic resources, such as the internet and other technologies—or technological literacy—plays a big role in consumer health informatics. One person with MS from embedded unit 3 phrased this as: “those who are not interested in technology would never use an app.”

It is important to keep in mind that the information gathered by mobile devices can be taken advantage in a way that improves the overall experience. If we crosscheck the fact that a cancer patient is in a specific GPS position every Thursday at 2 pm for 4 hours with the fact that this location is the oncology department of the local hospital, we could infer that they are undergoing chemotherapy. Knowing this could prove useful for recommending suitable actions for this context and patient, perhaps offering educational reading material during this period or even withholding suggestions for physical activity immediately after. Having a personalized experience reportedly helps persons with chronic conditions feel that a given solution is right for them; this was felt in embedded unit 3. In embedded unit 4, mHealth capabilities were used to learn about the user’s habits and, once sufficient information was gathered, a personalized recommendation system took over. The illustrative design questions for this section and their audit trail summary are presented in Textbox 8.

Textbox 7. Quantification illustrative questions.

Tracking (embedded units 1, 3, and 4)

- Does the condition have parameters that need to be tracked?
- What kind of parameters are we as mHealth designers interested in following?
- Do the technological capabilities allow for direct tracking?
- How accurate are the devices we will use for keeping track?
- How reliable are the device tracking capabilities?

Monitoring (embedded units 3 and 4)

- Does remote monitoring help the care process?
- How can we as mHealth designers enable health care professionals to follow the target population?
- Are intended users able to control what is being monitored?
- Are communication channels offered to health care professionals to contact the intended users?
- What role are we offering for the social circle within our design?

Feedback (embedded units 1, 3, and 4)

- How are we as designers letting intended users know of their progress?
- In what ways does our designed system notify intended users about corrective actions?
- How are we as mHealth designers encouraging intended users to perform the desired actions?
- What metrics are we as mHealth designers providing the intended users?

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Textbox 8. Tailoring illustrative questions.

Context awareness (embedded units 1 and 4)

- How are we as designers using the technological capabilities to learn about our intended users?
- What kind of information can we as designers learn directly through the device? Are there ways to indirectly gain more information?
- Does the use of geolocalization provide us as mHealth designers with useful insights?
- Would using social media information benefit our understanding of the situation of the intended users?

Just-in-time recommendations (embedded units 1 and 4)

- How can we as designers find the right moment for making a recommendation through technology?
- Are there different levels or types of actions that we as designers want the intended users to take?
- What kind of prompting do we as designers want to provide our intended users?
- How do we as designers evaluate the validity of our suggestions to intended users?

eHealth relationship (embedded unit 3)

- What do intended users feel about technology in general?
- Do intended users seek out online health information?
- How likely are our intended users to use technology to help them with their condition?
- Do intended users feel they have enough skills to use the technology?
- What causes our intended users to start and stop using a technological solution?

Representation

As methods for tracking all sorts of patient-related data are continuously being developed, we need to find ways in which this information is presented in a meaningful and relevant way to patients. Data by itself does not provide valuable insights on its own: it must be gathered, organized, made interpretable, and then analyzed to be of any use. Turning statistics into actionable information is what makes a difference.

In embedded unit 3, the health care professionals who worked with persons with MS said that it was often helpful to have some sort of visual representation to aid in the education and rehabilitation. The patients themselves also viewed this as important; for instance, PWMS06 felt that:

> *[In general, if you want] to convince people that physical activity is the key, we need to give them targets. Having feedback to how you are doing is good. We need to know we are doing something right.* [PWMS06]

Representing information in didactic ways allows persons with chronic conditions to see connections with their actions and better interpret data. The mHealth solution designed in embedded unit 4 represented the patient's overall energy through a progress bar composed of Stamina Credits, a unit we devised to quantify the estimated effort an activity might take. In this manner, persons with MS had a more tangible notion bridging the gap between the abstract concept of "energy" to a representation of the actual experience at the end of the day. The illustrative design questions for this section and their audit trail summary are presented in Textbox 9.

Model Summary

The work from embedded unit 1 provided a clearer picture of the current landscape for mHealth solutions for chronic conditions. Through these studies, the intended purposes, content reliability, and involved stakeholders in the development of these health apps is now known. These studies also hinted at the current gamification trend in mHealth for motivating users, which was explored in embedded units 2 and 3.

The 3MD for Chronic Conditions follows user-centered philosophy, in line with the work of embedded units 3 and 4, to take into account the perspectives from the different stakeholders involved in the care of a chronic condition, as well as the dynamics and elements that can create behavioral change. In embedded unit 4, the requirement negotiation between the medical knowledge, BCMs, and gamification was integrated and fostered the construction of this model.

Figure 5 shows the design factors of the 3MD. Designers are suggested to use the different groups of illustrative questions for inspiration and to make sure that no key element is left behind in their design.

The components of the 3MD for Chronic Conditions nurture and build on top of each other and are interconnected and interdependent. A condition-specific issue can affect our choice of behavioral change model in the same way that the selection of a technology-based issue can alter the overall experience. A negotiation between all components must happen so that these factors properly align to produce our mHealth solution. Further, the model has been intentionally developed in a way that allows it to be used simultaneously with other existing frameworks for design and analysis.

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Textbox 9. Representation illustrative questions.

Didactic (embedded units 3 and 4)

- Are we as designers expressing the information in a friendly manner?
- How are we making the call to action clear to our intended users?
- Are we as designers presenting easy to follow steps for the intended users?
- Can we as designers break down the information in smaller and easier to comprehend segments?

Dynamic (embedded units 3 and 4)

- How are we as designers taking advantage of the mHealth technological capabilities to communicate our meaning to our intended users?
- How are we accounting for different learning styles in our intended users?
- What kind of metaphors or analogies can we as designers use facilitate comprehension?
- Can we as designers use animations or simulations to represent key concepts?

Meaningful (embedded units 3 and 4)

- Are we as designers giving the intended users meaningful choices within our design?
- Can we as designers show how each action is personally connected to our intended users?
- Does our design highlight the benefits for the intended users?
- Are we as designers setting realistic expectations for the intended users?
- How can we as designers make the experience more relevant to our intended users?

Figure 5. Factors of the Model for Motivational Mobile-health Design (3MD).

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Designers are to view this model as a tool to help guide how to approach the problem of designing behavioral change mHealth solutions for chronic conditions. During the design process, designers are encouraged to use the illustrative questions as items to explore and find answers within their own project. These questions prompt the designers to understand what may be missing in their design and needs to be addressed.

Discussion

Principal Findings

The main contribution of this work lies in that it proposes a model that is unique because it demonstrates how different disciplines can be combined in a meaningful way to address a gap in the current body of knowledge. It also furthers the understanding of what to consider and to explore in the design of new behavioral change mHealth solutions.

The proposed model addresses the gap in the current body of knowledge regarding the combination of condition-specific knowledge with the understanding of technological opportunities and human factors. This research combines these three factors, which have been studied as separate elements in previous research, and shows how this integration reveals new and meaningful aspects about designing mHealth solutions for chronic conditions. Behavior change support systems are a relatively new area of research; therefore, theoretical efforts made for promoting scientific research in the area are valuable.

The proposed model can help designers to understand factors for the design of mHealth solutions and it offers illustrative design questions that can be used by mHealth designers from different disciplines to recognize and integrate factors relevant in designing mHealth solutions for chronic conditions.

Comparison With Prior Work

Health IT for the promotion of healthier lifestyles seems to be one of the most prominent areas for the future of health care [115] with this area receiving increasing attention from the technological sector and investors [19,116]. The need for health IT solutions to be engaging has been repeatedly highlighted in the literature [117,118] because evidence-based interventions are significantly more impactful [27]. Behavioral theory and UCD have widely acknowledged merits in their application to digital health interventions. Many have underscored the need for digital health interventions to be grounded in behavioral theory [17,119,120], designed with in-depth understanding of the target population [121], and developed involving the relevant stakeholders [122,123]. The 3MD for Chronic Conditions is the first to identify how health behavioral change theories and gamification can be used for user-centric design of mHealth solutions for persons with chronic conditions. The components and themes presented in this model emerged from explorations of the mHealth state of the practice, frequently used BCMs, and interactions with persons with chronic conditions and their caregivers.

There are current trends in the design of health IT that point out how solutions should engage users in meaningful ways [117,118] and understanding what the intended users go through helps the design process. Patient experience has been recognized as one of the pillars of quality in health care, along with clinical effectiveness and patient safety [124]. This experience is their personal interpretation of the service process and how they related to it during the course of each interaction [125]. These methods are largely inspired by the field of human-centered design in which the user perspective is seen as a central component to the design process [126]. The concept of the patient journey describes all the sequential steps in providing a patient's care, including clinical and nonclinical steps.

The 3MD for Chronic Conditions takes into consideration the context of the person with a chronic condition and its narrative. Understanding the context of a person is useful to approach their problems in a more integrative way. White and Epston [127] proposed that we create meaning by structuring our experiences into stories, which are accounts of our lived experiences put in sequence across time. The story provides a sense of continuity and meaning as it gives the past a history, it brings order to the present and attempts to predict a future. There is an emerging narrative that occurs from living with a condition. This narrative provides meaning, context, and sometimes perspective for the patient's situation. Disease management is an ongoing situation for these conditions and transitioning into this new normal is quite a problem. The new normal state may comprise rehabilitation, oncological treatment, insulin management, physiotherapy, or sometimes even palliative care. Reaching a normalcy state is key for living with chronic conditions; patients do their best to see themselves as essentially normal persons leading normal lives [128]. Normalizing the situation becomes a necessity and several mechanisms play a role. It is common practice for people in these situations to engage in acts of covering up behaviors, including minimizing physical activity to hide fatigue symptoms, desensitization measures such as making fun of their own disability, and making trade-offs, such as accepting less desirable circumstances just to be able to do what they wanted to do [129]. The 3MD places a strong focus in understanding the context of the target population and the intended intervention. This is in line with what has been stated in the literature as fundamental in the development of behavioral change digital health interventions [48,74]. Other design models such as the PSD [74] and the IDEAS model [75] agree on the importance of fully understanding contextual factors, but are not specific for mHealth solutions or chronic conditions.

The 3MD for Chronic Conditions was intentionally designed to be agnostic to specific BCMs making it easier to adapt to different theories as needed. There are many recommendations to use multiple theories for health behavioral change [71]; by prompting reflection on the intended behavioral intervention aspect, the model favors an integrative approach.

As a model for mHealth solutions design, 3MD for Chronic Conditions places particular consideration on the capabilities and challenges that mobile technologies offer. When building mHealth solutions, there is a variety of settings and possibilities that need to be accounted for. For example, a solution that supports an existing chronic disease management program differs from a standalone app in many ways [76]. The Chronic Disease mHealth App Intervention Design Framework [76] integrates clinical and behavioral change evidence for

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intervention and feature design, but is not focused on the users and their needs. In the same manner, it does not address the issue of engagement.

In many behavior change interventions, technology is still used as a passive medium that mostly serves to expedite the process of communication with the user. Behavioral change interventions that take advantage of the mobile capabilities can rapidly adapt based on the individual's current and past behavior and situational context [17]. The concept of "just-in-time" of Intille et al [130] is used to characterize interventions that adjust based on data obtained during the intervention. Additionally, standard health interventions have to consider the capacity of the intended users to process and understand basic health information, called health literacy [131]; mHealth designers need to also consider how technologically literate their users will be [105]. The 3MD for Chronic Conditions acknowledges the importance of these issues and specifically presents aspects to address them in a manner that can provide valuable insight for designers.

Behavioral change interventions have been identified as potential areas for the application of gamification [48,132]. The 3MD considers gameful design as an engagement tactic that can be tailored for the target population, the intended intervention, and the type of experience we are trying to achieve. Gamified systems have been described as complex interventions on themselves; the overreliance on points systems and disregarding contextual factors have led to unsuccessful gamification [92,133]. Thorough analysis of the content, structure, and delivery of the intervention and its components is needed for a desirable outcome [134,135]. Gamification design frameworks such as Werbach and Hunter's [89] or the Octalysis [90] provide notions that can be helpful for designers, but were not created with health care scenarios in mind. Health-oriented gamification frameworks such as the Wheel of Sukr [92] or PACT [93] exist and, although useful, they focus on diabetes care and rehabilitation systems, respectively. The 3MD for Chronic Conditions aims to go beyond one particular condition and into chronic condition care. The components presented in this model provide a conceptual way to help approach the challenges that designing an engaging behavioral change mHealth solution for chronic conditions poses.

Unlike other available design frameworks that are used to explain or describe how mHealth design should be embarked on, the proposed model also offers a series of illustrative design questions that can be used by designers to better understand the problem at hand and how to address it. The need for more concrete guidance in mHealth design has been highlighted often [75,136] and can be particularly important, keeping in mind that the bulk of consumer health informatics mHealth solutions seem to be designed by small companies and entrepreneurs [100,101].

Finally, the absence of health care provider involvement in the design of health IT has been raised in many occasions [137-141] is addressed within this model. Active involvement and participation from all relevant stakeholders are contemplated in the design process through the use of 3MD for Chronic Conditions.

Limitations

This work should be interpreted in the context of its limitations, which are discussed subsequently.

There are inherent limitations to the embedded case study methodology. The features that case study methodology offers that provided the rationale for its selection, also present certain limitations in its usage. Some authors [142] have commented how case study methodology may lack representativeness, rigor in data collection, construction, and analysis of the empirical materials. As the investigator, I was the primary instrument of data collection and analysis; therefore, my subjectivity is vulnerable to the problem of bias. However, the issues often raised against qualitative studies are so only in light of certain epistemological views. Qualitative approaches take into account and include differences; they do not attempt to eliminate what is inherent to being human and cannot be discounted [96,142,143]. During idea generation, designers also use their background experiences and skills, as well as different types of internal and external stimuli they might have access to [144]. Further, the audit trail is provided to help increase transparency.

The use of methodological triangulation opens the possibility of disharmony based on conflicts of theoretical frameworks and differences in the epistemologies of each method used in subcases [145]. However, the findings from these methods were considered as different parts of a knowledge continuum in line with Foss and Ellefsen [146], aiming to improve the accuracy of my findings and to increase their scope [94,95].

Additionally, this model is the outcome of mHealth design exploration in which only two conditions were considered, which leaves room to question the generalizability of its results. Another important aspect is that the model does not consider the fact that there are chronic patients who live with more than one chronic condition. Multimorbidity, as this phenomenon is called, is known to impact on health care costs and resources across health systems, regions, disease combinations, and person-specific factors (including social disadvantage and age) [147]. However, this was so because the creation of the model was driven by the different cases that I had the opportunity to work on and there was no mention of other concurrent conditions. Even so, the way the model is conceived allows for generation of further subthemes within the components that could accommodate multiple conditions.

From a design perspective, the proposed model uses experiences that stem from a single design case in which the design evaluation did not involve the intended end users. However, the model was systematically constructed based on the different studies and related work and, because it follows empirical evidence, its results are still valid.

Finally, as this model uses gamification in one of its factors, it is possible that in the future the use of game elements in health trend will turn out to be just a fad [29], and this subcomponent could lose its relevancy. Notwithstanding, the 3MD for Chronic Conditions uses gamification as a way to further explore and enhance motivational aspects; this subcomponent could be adjusted and amended in light of future findings.

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Future Research

Future research is necessary to validate the kinds of conclusions that can be drawn from the model proposed in this paper. More empirical design studies are needed to validate the 3MD for Chronic Conditions and assess its usability. This provides a good starting point for further research regarding the use of the model in different phases of the design cycle and how it can be approached by different stakeholders. The exploration of multimorbidity in the context of the proposed model may also constitute the object of future studies.

Conclusions

The results on this paper address a recognized gap in research and practice on how medical, design, and technology factors can guide the creation of mHealth solutions to face the global challenge that chronic conditions pose. Further, this work explores the design of behavioral change mHealth solutions for chronic conditions and proposes a model that could be of use in the generation of new tools to help chronic patients.

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Conflicts of Interest

None declared.

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Abbreviations

3MD: Model for Motivational Mobile-health Design
AIC: Akaike's information criterion
BCM: behavioral change model
BCSS: Behavioral Change Support System
eHealth: electronic health
HP: health care professional
IT: information technology
mHealth: mobile health
MS: multiple sclerosis
PSD: Persuasive Systems Design
PWMS: persons with multiple sclerosis
ROC: receiver operating characteristic
UCD: user-centered design

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Original Paper

Determining Physiological and Psychological Predictors of Time to Task Failure on a Virtual Reality Sørensen Test in Participants With and Without Recurrent Low Back Pain: Exploratory Study

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Abstract

Background: Sørensen trunk extension endurance test performance predicts the development of low back pain and is a strong discriminator of those with and without low back pain. Performance may greatly depend on psychological factors, such as kinesiophobia, self-efficacy, and motivation. Virtual reality video games have been used in people with low back pain to encourage physical activity that would otherwise be avoided out of fear of pain or harm. Accordingly, we developed a virtual reality video game to assess the influence of immersive gaming on the Sørensen test performance.

Objective: The objective of our study was to determine the physiological and psychological predictors of time to task failure (TTF) on a virtual reality Sørensen test in participants with and without a history of recurrent low back pain.

Methods: We recruited 24 individuals with a history of recurrent low back pain and 24 sex-, age-, and body mass index–matched individuals without a history of low back pain. Participants completed a series of psychological measures, including the Center for Epidemiological Studies-Depression Scale, Pain Resilience Scale, Pain Catastrophizing Scale, Tampa Scale for Kinesiophobia, and a self-efficacy measure. The maximal isometric strength of trunk and hip extensors and TTF on a virtual reality Sørensen test were measured. Electromyography of the erector spinae, gluteus maximus, and biceps femoris was recorded during the strength and endurance trials.

Results: A two-way analysis of variance revealed no significant difference in TTF between groups (*P*=.99), but there was a trend for longer TTF in females on the virtual reality Sørensen test (*P*=.06). Linear regression analyses were performed to determine predictors of TTF in each group. In healthy participants, the normalized median power frequency slope of erector spinae (beta=.450, *P*=.01), biceps femoris (beta=.400, *P*=.01), and trunk mass (beta=−.32, *P*=.02) predicted TTF. In participants with recurrent low back pain, trunk mass (beta=−.67, *P*<.001), Tampa Scale for Kinesiophobia (beta=−.43, *P*=.01), and self-efficacy (beta=.35, *P*=.03) predicted TTF.

Conclusions: Trunk mass appears to be a consistent predictor of performance. Kinesiophobia appears to negatively influence TTF for those with a history of recurrent low back pain, but does not influence healthy individuals. Self-efficacy is associated with better performance in individuals with a history of recurrent low back pain, whereas a less steep median power frequency slope of the trunk and hip extensors is associated with better performance in individuals without a history of low back pain.

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KEYWORDS

fatigue; low back pain; Sørensen test; trunk mass; virtual reality

Introduction

Low back pain (LBP) represents a significant societal and economic burden [1] with direct medical costs approaching US $100 billion annually in the United States alone [2]. These costs are driven primarily by the 10%-15% of individuals who develop chronic LBP [1,3]. Poor trunk extension endurance has been identified as a risk factor for the development of LBP [4]. Specifically, poor time to task failure (TTF) on the Sørensen back extension endurance test, which requires an individual to maintain the upper body in an unsupported horizontal position to the point of fatigue, predicts first-time episodes of LBP [5,6] and chronic LBP [7]. Although the Sørensen test has been used for the identification of LBP risk, the underlying mechanisms driving poor performance on the test are not well understood. Research has demonstrated that in addition to physiological factors, such as median power frequency (MPF) slopes of the trunk and hip extensors and anthropometrics, psychological factors must be considered in the assessment of performance on the Sørensen test.

Evidence suggests that individuals terminate the Sørensen test for reasons other than subjective fatigue; these reasons include pain, discomfort, fear, and lack of motivation [8]. Studies of rehabilitation motivation in clinical populations, such as those of individuals recovering from cardiac events, have demonstrated that although motivation is difficult to define and measure, it plays a crucial role in rehabilitation outcomes for patients [9]. Motivation could be manipulated through the use of distracting, immersive virtual reality gaming. Virtual reality games have been implemented for pain distraction in individuals receiving chemotherapy and during burn debridement, resulting in lower pain ratings and greater tolerance of treatments [10-12] and encouraging greater lumbar spine flexion in individuals with kinesiophobia and LBP [13]. Thus, by providing a distraction element to counteract fear cognitions during the assessment, a virtual reality video game could enhance motivation during the Sørensen test, leading to maximal effort.

However, psychological factors are likely still involved in performance on the Sørensen test. Self-efficacy contributes to the performance of physical activities. Self-efficacy is the magnitude of belief in one's ability to perform a certain task to achieve a specific outcome [14]. Self-efficacy is strongly associated with sports performance [15]. Although the study of self-efficacy regarding physical activity contributes to the understanding of human behavior, application to the Sørensen test, specifically, is limited.

The influence of fear of pain may vary as a function of prior LBP experience. Chronic pain is a biopsychosocial phenomenon; an individual's emotions and appraisal of pain contributes to chronicity [16]. Cognitive appraisal of pain varies based on individuals' beliefs about their ability to cope with pain. In many situations, pain can elicit negative emotional reactions that lead to the amplification of pain experiences [17]. Individuals with maladaptive emotional responses to pain who undergo traditional treatment for LBP may continue to experience pain and disability long after the symptoms are treated. A cognitive behavioral model of chronic LBP, termed the fear-avoidance model, explains the progression from acute pain to chronic pain and disability [18,19]. In addition, the model hypothesizes that an individual's pain experience depends upon their established levels of pain-related fear. Kinesiophobic individuals, those who are prone to avoidance of movement for fear of pain or harm, respond to pain with catastrophic thoughts (ie, "The pain will get worse if I attempt to overcome it"), leading to inactivity and further progression of disability [18,20].

Measures of kinesiophobia have been used to predict LBP [19]. Pain-related fear predicts reduced maximal force production and increased pain-related interference in daily activities, regardless of actual pain levels [21]. Moreover, kinesiophobia has been recognized as an integral factor in Sørensen test performance. Sørensen TTF "underperformance" in individuals with chronic LBP could be predicted, in part, by fear-avoidance beliefs, as well as self-efficacy [22].

A variation of the Sørensen test that uses a virtual reality video game could encourage maximal effort, counteract fear cognitions, and allow for more accurate identification of both the physiological and psychological factors driving performance. Accordingly, we have developed a variation of the Sørensen test that uses a virtual reality video game to provide motivation and distraction. This study aims to determine whether the use of a virtual reality video game influences performance on the Sørensen test and whether the predictors of TTF vary between individuals with and without recurrent LBP on the virtual reality Sørensen test.

Methods

Participants

A sample of 24 individuals (12/24, 50% male) with a history of recurrent LBP (LBP) and 24 individuals (12/24, 50% male) with no history of LBP (Healthy) matched for age, sex, and body mass index (BMI) were recruited from the Ohio University student population and surrounding community for this comparative study. Table 1 summarizes the participants' characteristics. Individuals with a history of hip arthroscopy or spine surgery, known neurological, visual, or orthopedic impairments, depression, ongoing drug or alcohol problems, elevated resting blood pressure (>135/>90 mmHG), or BMI of >35 were excluded from the study. We defined LBP history as having experienced more than one episode of LBP with symptoms occurring in the past 6 months and a previous consultation regarding their LBP symptoms with a health care provider; participants reporting moderate to severe pain (numerical pain rating scale of >3) within the past 6 weeks or those who did not meet the classification of category 1 (LBP that does not radiate) through category 3 (LBP that radiates beyond the knee but without neurological signs) on the Classification System of the Quebec Task Force on Spinal Disorders were excluded from participation. The protocol was

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approved by the Ohio University Institutional Review Board for human subjects research, and all individuals provided written consent prior to participation.

Instruments

Center for Epidemiological Studies-Depression Scale

The Center for Epidemiological Studies-Depression Scale (CES-D) was used in the general population to measure depressive symptomatology. Good predictive validity for the identification of depression in individuals with chronic pain has been established [22] as well as good sensitivity (93.2%) using a cutoff score of 19 (out of 60) for the identification of depression in individuals with chronic pain [23].

Pain Catastrophizing Scale

The Pain Catastrophizing Scale (PCS) is a 13-item scale that measures pain catastrophizing by assessing the degree to which the respondent experiences specific thoughts and feelings during pain on a 5-point Likert-type scale with the endpoints “Not at all” (0) and “All the time” (4) with a score of 30 indicating clinically relevant pain catastrophizing behavior. PCS has been identified as a reliable and valid measure of pain catastrophizing (Cronbach alpha=.87; test-retest intraclass correlation coefficient=.93). PCS is consistently associated with pain sensitivity and pain-related distress in experimental pain studies [24-26]. Furthermore, pain catastrophizing is a primary vulnerability construct [27,28].

Pain Resilience Scale

The Pain Resilience Scale (PRS) asks participants how they respond when faced with intense or prolonged pain by rating items on a 14-item Likert scale using a “Not at all” (0) to “All the time” (4) scale with higher scores indicating greater pain resilience. Strong internal consistency and acceptable levels of stability have been established (alpha=.93, intraclass correlation coefficient=.80) [29].

Tampa Scale for Kinesiophobia and Tampa Scale for Kinesiophobia-General Population

Two versions of the Tampa Scale for Kinesiophobia (TSK) were used in this study, each using 17 items on a 4-point Likert scale ranging from “Strongly disagree” (1) to “Strongly agree” (4) with scores >36 indicating clinically relevant kinesiophobia. The LBP group completed the standard TSK, which assessed fear of movement at the risk of injury or (re)injury. The healthy group completed the TSK-General Population (TSK-G), which used items modified to ask how much the respondent would fear movement at the risk of injury or (re)injury if they had LBP. In addition, construct validity and predictive ability has been established in LBP populations [30]. In the general population, TSK-G is also reliable and valid as a self-report measure of fear of movement and (re)injury [31].

Self-Efficacy Measure

The self-efficacy measure was developed for this study based on prior studies [32,33]. After practicing the task position for a brief period, participants were asked to indicate their confidence in their ability to maintain the Sørensen test position for 1, 2, 3, and 4 minutes on a scale ranging from “Not at all confident” (0) to “Highly confident” (100).

Data Collection

Participants completed 2 separate testing sessions. Participants in this study were first included in an assessment of performance on the classic Sørensen test [34] and were invited to participate in the virtual reality Sørensen test 3-14 days later. During the first testing session, participants completed the psychological surveys, maximal strength assessments, and the classic Sørensen test. During the second testing session, participants completed the virtual reality Sørensen test.

Electromyography Data

Electromyography (EMG) was performed as described previously [34]. In brief, EMG was collected using a 16-channel Delsys Bagnoli system (Delsys Inc, Boston, MA, USA; bandwidth 20-450 Hz); the bar leads were modified with clip leads to allow attachment to Ag-Ag Cl surface electrodes over the erector spinae (ERS) at the L2 and L4 level aligned between the posterior superior iliac spine and the lateral border of the muscle at the 12th rib, gluteus maximus midway between the greater trochanter and the posterior superior iliac spine, and long head of the biceps femoris (BF) midway between the fibular head and the ischial tuberosity. The raw surface EMG data were amplified (1k) and A/D converted with 16-bit resolution, sampled at 1000 Hz, and averaged across sides for each muscle.

Median Power Frequency

MPF was calculated as described previously [35]. Using a fast Fourier transformation with a 512-point Hamming window, the EMG power spectrum for each muscle was calculated. MPF was determined using a 2-second moving window with 50% overlap. The normalized slope of MPF was determined as follows: (MPF slope/initial MPF)x100 [35]. All processing of EMG data were performed with custom software written in MATLAB (Version 2016b; The MathWorks).

Table 1. Participant characteristics.

Characteristics	Healthy (n=24), mean (SE)	Low back pain (n=24), mean (SE)
Age (years)	29.2 (2.2)	24.3 (1.5)
Height (m)	1.7 (0.0)	1.7 (0.0)
Weight (kg)	73.3 (2.6)	71.4 (2.6)
Body mass index (kg/m^2)	24.8 (0.7)	24.2 (0.7)

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Force Output and Torque Moment Data

The maximal voluntary contraction data were measured as described previously [34]. In brief, our custom articulated fatigue table integrated a 6 degree of freedom (DOF) load cell (MC5-1250; AMTI, Watertown, MA, USA) into the trunk platform connected to a signal conditioner (GEN 5; AMTI), and single DOF load cell (XTS4-500; Load Cell Central, Milan, PA, USA) into the leg brace connected to an analog signal conditioner (OM19; Load Cell Central). Force and torque data were A/D converted at 16-bit resolution and sampled at 1000 Hz.

Position Data

The trunk position during the Sørensen test was measured as described previously [34]. In brief, custom-made potentiometers were anchored over the participant's sacrum at the level of L5-S1 and trunk at the level of T12-L1. An algorithm converted the potentiometers' voltages into position (degrees of rotation) with excellent linearity of fit (R^2=0.9988). Our custom LABVIEW (Version 13; National Instruments, Austin, TX, USA) program used the algorithm to track the position during the Sørensen tests. The horizontal position was individually calibrated prior to each test.

Maximal Voluntary Contraction Procedure

The maximal voluntary contraction procedure was completed as described previously [34]. As illustrated in Figure 1, subjects were situated on the custom fatigue table with the anterior superior iliac spine aligned with the edge of the table and the torso supported by the platform positioned such that the trunk center of mass was centered over the 6 DOF load cell. In addition, the torso was secured to the platform, the pelvis was secured to the table, and the lower legs were secured at 33% of hip height by a padded bar connected to the single DOF load cell. Bracing of the feet was inhibited with a foam roll placed below the ankles. The trunk mass was measured in this position. EMG was measured as previously described and the custom LABVIEW (Version 13; National Instruments) program collected EMG and load cell measurements.

For the trunk extension trials, participants were instructed to pull their torso up into the back restraint. Three submaximal trunk extension attempts of increasing intensity were followed by 3 maximal trunk extension attempts. Then, participants were instructed to extend their legs up against the stationary leg restraint; 3 submaximal hip extension attempts of increasing intensity were followed by 3 maximal attempts. We provided 2 minutes of rest between each attempt. Verbal encouragement and visual and audio feedback were provided via the custom LABVIEW (Version 13; National Instruments) program.

Virtual Reality Sørensen Procedure

The participants performed the virtual reality Sørensen test on a standard table with belts across the pelvis and calves at 33% of hip height, the anterior superior iliac spine aligned with the edge of the table, and the upper body unsupported, as seen in Figure 2. Subjects wore an Oculus Rift head mounted display (Oculus Rift Developers Kit 2), as shown in Figure 2. During the test, the Oculus Rift displayed a sky environment in which the participant attempted to "fly" through hoops, as seen in Figure 3. Extending and flexing the trunk appeared to make the subject fly higher and lower, respectively. The hoops were positioned such that the participants were encouraged to maintain a horizontal position for as long as possible. Immediately following a brief practice attempt of <5 seconds, participants completed the self-efficacy questionnaire.

Figure 1. Experimental setup on the fatigue table for maximal voluntary contraction of the trunk and hip.

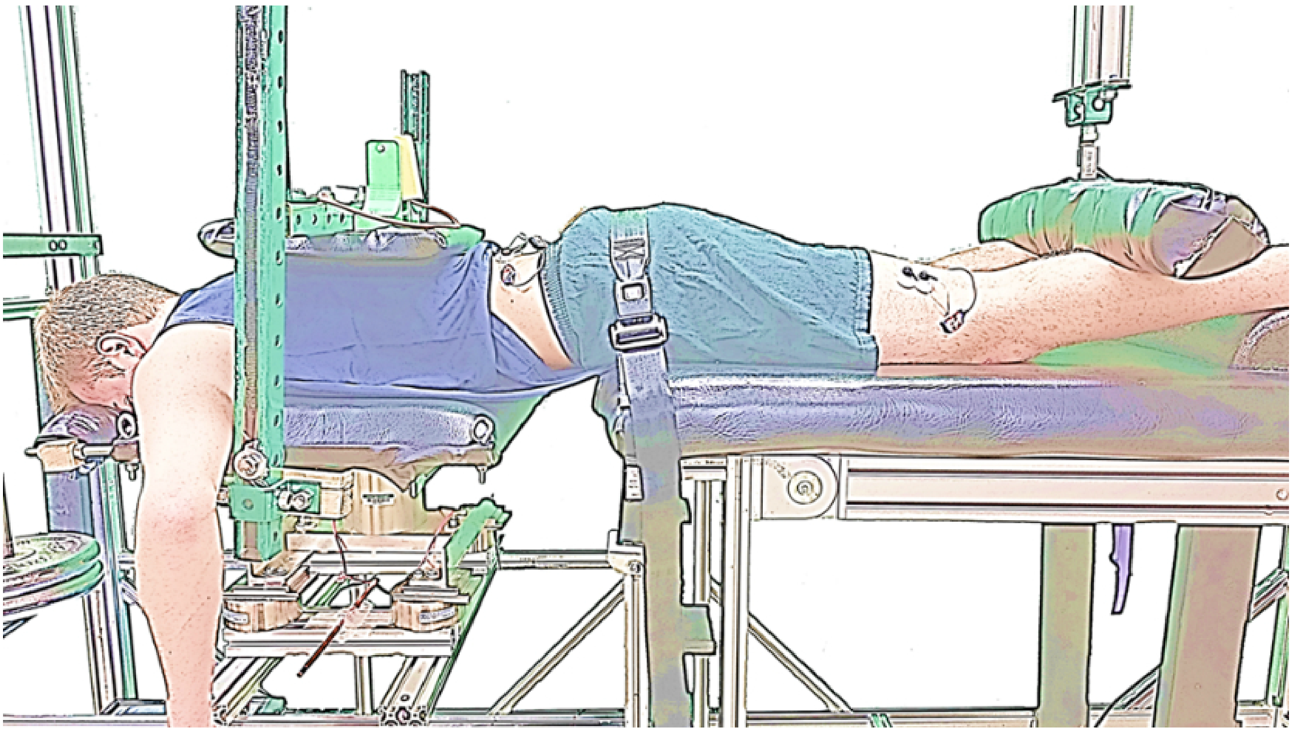

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Figure 2. Experimental setup on the standard table for the virtual reality Sørensen test.

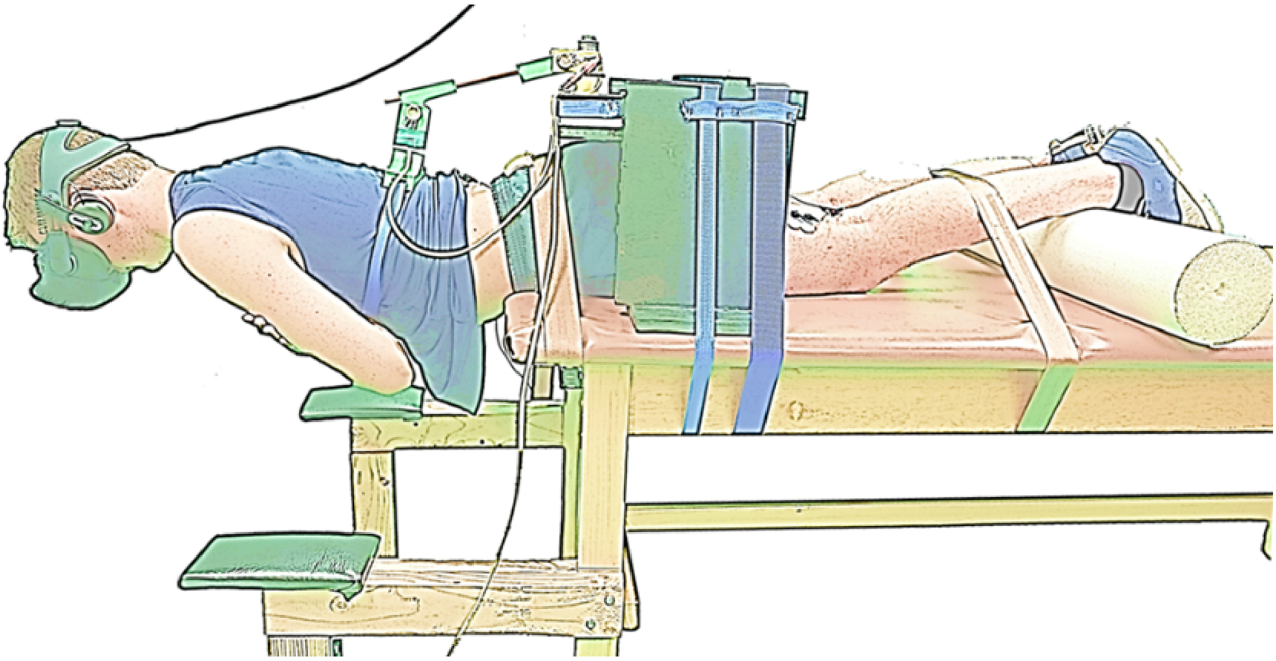
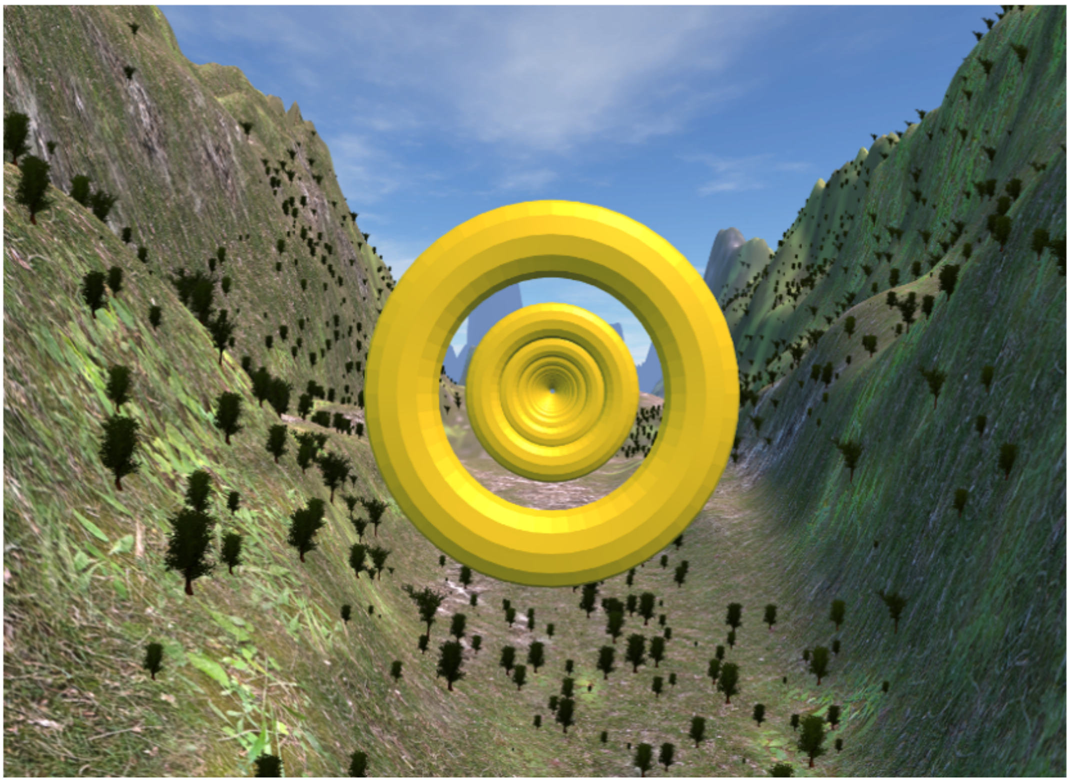


Figure 3. Participant's perspective during gameplay, displayed through the Oculus Rift headset.



Participants then attempted to maintain the task position until failure while receiving audio and visual feedback through the virtual reality video game; a tone played when the participant's position was >2° beyond the target position in either direction, which was visually represented by flying above or below the hoops. The trial was terminated when participants fell out of the range (±2°) for >3 consecutive seconds.

Statistical Analysis

In this study, independent-sample *t* tests were used to evaluate differences in participant demographics. A two-way analysis of variance was used to determine group and sex differences in TTF on the virtual reality Sørensen test. In addition, stepwise linear regression analyses were performed to determine which physiological factors were related to TTF on the virtual reality Sørensen test in each group. The second set of linear regression analyses was performed with the significant physiological

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factors entered into the first block and psychological factors entered stepwise in the second block to determine which psychological factors were related to TTF on the virtual reality Sørensen test in each group. All analyses were performed in SPSS (IBM Corp.), and results are reported as mean (SE) unless otherwise stated.

Results

Demographics

The independent-sample *t* test revealed no significant differences between Healthy and LBP groups with one exception; the depression scores were significantly higher in the LBP group than in those the healthy group (Table 2).

Time to Task Failure

A 2 Group (Healthy, LBP) x 2 Sex (Male, Female) two-way analysis of variance revealed no significant differences in group ($F_{1,44}$=0.00, *P*=.99) or group by sex ($F_{1,44}$=0.33, *P*=.57; Table 3); however, there was a marginal effect of sex ($F_{1,44}$=3.89, *P*=.06), which reflected a tendency toward the longer TTF in female versus male participants.

Predictors of Virtual Reality Sørensen Time to Task Failure

Simple correlations were run between TTF and each of the physiological and psychological factors that were entered into the linear regression analyses. Table 4 displays the Pearson correlations.

Healthy

A stepwise linear regression analysis identified the normalized MPF slope of ERS (beta=.45, *P*=.01), normalized MPF slope of BF (beta=.40, *P*=.01), and trunk mass (beta=−.32, *P*=.03) as significant predictors of TTF. A separate linear regression analysis was then run with the MPF slopes of ERS and BF; trunk mass was entered into the first block and all psychological measures (ie, CES-D, TSK, self-efficacy, PCS, and PRS) were offered stepwise into the second block. Only trunk mass and the normalized MPF slopes of ERS and BF were retained as significant predictors of TTF on the virtual reality Sørensen test in the healthy group (Table 5).

Low Back Pain

A stepwise linear regression analysis identified the trunk mass (beta=−.53, *P*=.01) as a significant predictor of TTF. A separate linear regression analysis was then run with trunk mass entered into the first block, and all psychological measures (ie, CES-D, TSK, self-efficacy, PCS, and PRS) were offered stepwise into the second block. In the final model, the trunk mass (beta=−.67, *P*=.001), TSK (beta=−.43, *P*=.01), and self-efficacy (beta=.35, *P*=.03) were retained as significant predictors of TTF on the virtual reality Sørensen test in the LBP group (Table 5).

Table 2. Anthropometric, strength, and psychological survey measures.

Survey measures	Healthy (n=24), mean (SE)	Low back pain (n=24), mean (SE)	*P* value
Trunk mass (kg)	36.7 (1.5)	35.4 (1.6)	.54
Trunk length (m)	0.5 (0.0)	0.4 (0.0)	.15
Vertical trunk force (N)	476.7 (52.8)	511.7 (35.4)	.65
Trunk moment (Nm)	42.3 (4.1)	45.4 (5.4)	.66
Hip force (N)	131.0 (8.2)	138.4 (8.6)	.50
Erector spinae MPF[a] slope (%/s)	−0.1 (0.0)	−0.1 (0.0)	.32
Gluteus maximus MPF slope (%/s)	−0.3 (0.0)	−0.2 (0.0)	.16
Biceps femoris MPF slope (%/s)	3.8 (0.8)	7.6 (1.2)	.38
Depression (0-60)[b]	39.3 (2.1)	37.7 (2.1)	.01
Pain resilience (0-56)[b]	7.6 (1.3)	6.8 (0.9)	.61
Pain catastrophizing (0-52)[b]	30.9 (1.2)	32.0 (1.3)	.59
Kinesiophobia (17-68)[b]	38.7 (4.1)	44.5 (3.2)	.54

[a]MPF: median power frequency.

[b]Ranges for the scales.

Table 3. Time to task failure on the virtual reality Sørensen test.

Participants	Healthy, mean (SE)	Low back pain, mean (SE)	Total, mean (SE)
Male	107.2 (9.6)	98.1 (9.7)	102.7 (6.7)
Female	128.7 (21.1)	137.3 (17.8)	133.0 (13.5)
Total	118.0 (11.6)	117.7 (10.7)	117.8 (7.8)

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Table 4. Simple correlations between time to task failure and factors entered into the linear regression analyses.

Measures	Healthy		Low back pain	
	r	*P* value	*r*	*P* value
Trunk mass	−0.467	.02	−0.532	.01
Trunk length	0.180	.40	0.016	.94
Vertical trunk force	0.065	.76	−0.061	.78
Trunk moment	−0.248	.24	−0.200	.35
Hip force	−0.056	.80	−0.299	.16
Erector spinae MPF[a] slope	0.616	.001	0.314	.14
Gluteus maximus MPF slope	0.440	.03	−0.174	.42
Biceps femoris MPF slope	0.513	.01	0.418	.04
Self-efficacy	0.525	.01	0.235	.27
Depression	0.128	.55	−0.194	.36
Pain catastrophizing	−0.158	.46	−0.091	.67
Pain resilience	−0.030	.89	−0.362	.08
Kinesiophobia	−0.106	.62	−0.276	.19

[a]MPF: median power frequency.

Table 5. Significant factors identified by the linear regression analyses.

Factor	Unstandardized beta	SE	Standardized beta	*t*	*P* value
Healthy					
(Constant)	301.32	10.20	—	7.50	<.001
Erector spinae MPF[a]	140.21	45.17	.45	3.10	.01
Biceps femoris MPF	130.24	44.74	.40	2.91	.01
Trunk mass	−1.12	0.49	−.32	−2.30	.03
Low back pain					
(Constant)	342.21	61.68	—	5.55	<.001
Trunk mass	−2.08	0.48	−.67	−4.34	<.001
Kinesiophobia	−3.56	1.27	−.43	−2.81	.01
Self-efficacy	1.15	0.49	.35	2.34	.03

[a]MPF: median power frequency.

Discussion

Principal Findings

This study aimed to examine the performance on a variation of the Sørensen test using a virtual reality video game in individuals with and without a history of recurrent LBP. To the best of our knowledge, this is the first study to use a virtual reality video game in conjunction with the Sørensen test. Contrary to much of the published literature, we did not find a significant difference in TTF between the groups. In the first longitudinal study, males with a short TTF on the Sørensen test were most likely to experience LBP in the following year, identifying the test as a predictor of first-time LBP [36]. The test was later recognized as a discriminator of those with and without LBP; individuals who had no prior LBP experience exhibited a markedly longer TTF than those with any LBP experience [37]. Many studies have reported consistent findings; however, others have failed to find a difference in performance between those with and without LBP. Many physiological factors, including the BMI, trunk mass, MPF slopes of the trunk and hip extensors, and maximal trunk and hip strength, have been found to influence the performance on the task; these factors have been discussed previously [34].

Although our sample of individuals with recurrent LBP performed just as well on the virtual reality Sørensen test as those without LBP, several interesting findings regarding the factors associated with TTF emerged. In the healthy group, it appears that TTF was driven primarily by trunk mass and the MPF slopes of the trunk and hip extensors, and this is consistent with our previous work [34]. In addition, trunk mass was a predictor of TTF in the LBP group. Other studies also demonstrated the marked effects of anthropometrics on

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performance. The workload of the task is governed by the weight of the body above the hips. It is obvious that an individual with a heavier trunk mass will not be able to maintain the test position for as long as another individual with the same strength capacity but lighter trunk mass. The effects of anthropometrics tend to be consistent in both individuals with and without LBP. Previously, marked associations have been identified between body mass, BMI, and the MPF slope of ERS in males and females with and without LBP [38]. Moreover, a marked association between TTF and torso mass in females with and without LBP has been demonstrated [39]. Trunk mass is an important factor in Sørensen test TTF, especially in those with a history of LBP, and should be considered when assessing performance. A variation in the Sørensen test that normalizes the workload to a consistent percentage of maximal strength would account for differences in trunk mass and strength to allow for a more objective assessment of endurance.

In this study, self-efficacy emerged as an important factor in Sørensen test performance. Motivation has long been recognized as a consequential factor in Sørensen test performance [22,36,40-43]; however, to the best of our knowledge, we are the first to attempt to manipulate it through the use of a virtual reality video game. The self-efficacy measure was created specifically for the Sørensen test task, which likely explains its strong association with TTF in the LBP group. Interestingly, self-efficacy was not predictive of performance in the healthy group. Thus, in this sample of individuals without a history of LBP, it appears that self-efficacy did not drive performance. Alternatively, our sample of individuals with a history of recurrent LBP performed better on the virtual reality Sørensen test if they reported higher ratings of confidence in their capacity to perform the task; this is consistent with our previous findings on the standard Sørensen test [34] as well as those obtained by others who found that performance was predicted, in part, by self-efficacy [22]. This would suggest that self-efficacy may be a worthwhile target for cognitive behavioral interventions for LBP.

In addition, there was a significant effect of kinesiophobia in our LBP group; those who had lower TSK scores maintained a longer TTF on the virtual reality Sørensen test; this would suggest that TSK is predictive of performance in individuals with recurrent LBP when provided with a distraction element. On the classic version of the Sørensen test [34], TSK was not predictive of performance in this same group of individuals with recurrent LBP. The virtual reality video game may have actually exacerbated fear cognitions by blocking the participant's view of the real world, reducing their sense of control, and instead redirecting focus toward their pain-related fear. Moreover, it is possible that attentional resources were reduced in response to the game. Future research could benefit from investigating the response to different types of games to determine whether certain games are more effective or whether games are not effective in any form to counteract pain-related fear.

Previous research has demonstrated an effect of sex on performance on the Sørensen test. Females tend to maintain the test position for longer than males [43,44]; however, several studies have found no sex differences [45,46], and others have found that males maintain the test position for longer than females [47-49]. We did identify a trend toward a sex difference on TTF with females maintaining the position slightly longer than males (P=.06). Others have reported that healthy females maintained an isometric trunk extension task markedly longer than healthy males [50]. The authors attributed their results to the muscle mass and strength hypothesis, which describes the relationship among the total muscle mass, vascular compression, and the demand for oxygen. According to this hypothesis, because females typically have lower muscle mass, the vasculature is less compressed during isometric exercise, and the demand for oxygen to the active muscles is lower [51,52]. There is some evidence that females have a greater ratio of type I oxidative muscle fibers in the trunk extensors [53], which would have a greater concentration of beta-2 adrenergic receptors, enhancing vasodilation [54]; there is also evidence that females have a greater degree of capillarization in some muscles [55], enhancing perfusion. However, others have demonstrated that intramuscular pressure may not be associated with a shift in MPF during isometric trunk extension exercises [56,57]. Although muscle mass was not measured in this sample, it is possible that TTF was influenced by perfusion.

Limitations

As with any study of human subjects, this study is not without its limitations. Our LBP group consisted of individuals with mild, recurrent LBP, which may have also restricted the sample to individuals with low levels of disability and pain-related fear. Individuals with higher disability and pain-related fear have poorer rehabilitation outcomes and typically perform more poorly on the Sørensen test. Thus, significant pain-related fear associations may have emerged in a sample of individuals with more severe kinesiophobia and disability symptoms. In addition, this group was primarily young, fit, college-aged students; future studies will benefit from measuring physical activity levels because cardiorespiratory fitness is likely associated with performance on any endurance task, such as the Sørensen test.

Conclusions

This study demonstrates that individuals with and without mild, recurrent LBP perform similarly on a variation of the Sørensen test using a virtual reality video game, but the underlying mechanisms driving performance vary between the groups. Performance on this variation of the Sørensen test in healthy individuals is driven primarily by physiological factors, including trunk mass and the MPF slopes of ERS and BF. In addition, trunk mass is an important factor of performance in individuals with a history of recurrent LBP; however, levels of self-efficacy and kinesiophobia also appear to be important predictors of TTF on this virtual reality Sørensen test.

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Conflicts of Interest

None declared.

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Abbreviations

BF: biceps femoris
BMI: body mass index
CES-D: Center for Epidemiological Studies-Depression
DOF: degree of freedom
EMG: electromyography
ERS: erector spinae
LBP: low back pain
MPF: median power frequency
PCS: Pain Catastrophizing Scale
PRS: Pain Resilience Scale
TSK: Tampa Scale for Kinesiophobia
TSK-G: Tampa Scale for Kinesiophobia-General Population
TTF: time to task failure

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Original Paper

Investigating the Relationship Between Eye Movement and Brain Wave Activity Using Video Games: Pilot Study

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Abstract

Background: All eye movements are related in one way or another to our mental processes with lateral eye movements being associated with the different hemispheres of the brain. Eye movement techniques form the basis of eye movement desensitization and reprocessing therapy, wherein forced eye movements activate neurological pathways to treat the subject.

Objective: The objective of our study was to examine the relationship between players' eye movements and their brain wave activities using a video game.

Methods: We used similar eye movement techniques in the form of a video game called *Lifeguard* that could potentially stimulate different eye movement mode and create a more engaging experience for the user. By designing an experiment, we further explored the differences in electroencephalogram spectral power activity for the alpha, beta, theta, delta, and gamma frequency bands in *Lifeguard* and *Tetris*.

Results: The game based on eye movement technologies resulted in decreased delta power and increased beta power, but significant difference between 2 games was not found.

Conclusions: The applied uses of this research could mean that eye movement desensitization and reprocessing can be conducted in a more fun and engaging way through the use of gaming technology.

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KEYWORDS

video games; games for health; eye movement desensitization reprocessing (EMDR); electroencephalography (EEG); player experience

Introduction

Background

Video games have been creating engaging experiences for entertainment purposes since 1970s. As computing power has continued to advance over the years, the sound, graphics, and complexity of video games have improved to create more stimulating experiences, and the application of games has expanded beyond entertainment to areas, such as education and health.

The use of biofeedback plays a key role in the form of video game treatment because it provides a quantitative measure of physiological state. Moreover, the use of real-time biofeedback provides a method that monitors changes in the effect of an individual during game play. By analyzing these changes and using the analysis results to influence the game, it is possible to regulate a person’s physiological metrics toward a specific state or to modify their behavior [1].

In this study, we aimed to use video game technologies, including motion graphics and emotionally charged scenarios, to explore the relationship between eye movements as well as game play and brain wave activities. Eye movement is involved in memory recall and disruption of normal eye movement patterns that form the basis of eye movement desensitization

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and reprocessing (EMDR) therapy, wherein forced eye movements activate neurological pathways to treat the participant [2-5]. Designing similar eye movement activities into video game play could create a more engaging experience for the user.

Games Designed to Improve Health

The experiences created by video games activate mental processes that regulate the autonomic nervous and endocrine systems; for example, in-game situations that induce fear activate the sympathetic nervous system and the endogenous production of adrenaline, cortisol, and norepinephrine.

Thus, video games provide a possible alternative to prescribing pharmaceuticals for treating behavioral and neuropsychiatric disorders. By entraining somatic awareness and behavioral skills acquired via game experience, individuals can slightly moderate their behavior in real-life situations and create a positive lifestyle change. Video games have been used in a beneficial manner to help treat overweight-related behaviors [6], prevention of alcoholism in adolescents [7], and posttraumatic stress disorder (PTSD) [8,9].

By specifically designed games to immerse a participant in a virtual reality environment, the PTSD symptoms of war veterans can be significantly reduced [8]. Instead of placing them in a potentially harmful situation, this will highlight the underlying negative cognitive patterns in a safe way. It has also been demonstrated that playing the video game *Tetris* for a short period of time immediately after an emotional experience can reduce its psychological impact [10]. In this experiment, after viewing traumatic materials, the unwanted, involuntary memory flashbacks of the participants who played *Tetris* for 10 minutes reduced.

Playing video games that promote learning sequences have reduced attention deficit hyperactivity disorder (ADHD) symptoms. Weerdmeester et al have found that 73 children with elevated ADHD symptoms improved in several areas with only a short amount of gameplay (1.5 hours) compared with those who played a game without ADHD-focused training components [11]. Peijnenborgh et al have developed a computer game called *Timo's Adventure* as an assessment tool for cognitive functions and tested its validity in normal developing children and children with ADHD [12]. The result has shown that the game could be a valid tool in assessing specific strengths and weaknesses of young children with ADHD. Meanwhile, Bul et al [13] have designed and implemented a serious game called *Plan-It Commander* as an adjunct to treatment for children with ADHD. They have found that several skills of the participants who received a serious game intervention significantly improved.

Previous studies have shown that PTSD and ADHD are correlated to brain activity. Veterans with PTSD are more likely to have decreased alpha power and increased beta power [14]. In individuals with ADHD, the aim is to decrease the theta band and increase the beta band, which corresponds to an alert and focused but relaxed state [15,16]. The horizontal eye movement training can also increase alpha amplitude and decrease delta amplitude, correlating with the subjective improvement of sleep quality and well-being as well as a sense of optimism [17].

Eye Movement

To explore the relationship between eye movements as well as game play and brain wave characteristics, the basic concepts of eye movement must first be understood. Mental processes stimulate all eye movements. Neurological activities, such as memory access, correlate to specific eye movement patterns.

Dilts et al has used electrodes to track both the eye movements and brain wave activities of participants who were asked to answer a series of questions about sight, sound, or kinesthetic feelings [2]. Specific eye movements were found to be correlated with brain activity during different cognitive tasks with shifts in eye movements directly relating to the part of the brain they were using; for example, lateral eye movements to either side are an indicator of internal auditory activity (ie, remembered sounds and words). Eye movements down and to the left are found to indicate internal dialogue or inner self-talk. Upward eye movements to either side are believed to indicate internal visual activity (ie, constructed imagery and visual fantasy). Moreover, Dilts et al has pointed out that for left-handed individuals, the down left and are merely reversed in this model.

EMDR is a form of psychotherapy that has been designed to relieve the symptoms of traumatic events, such as accidents, experiences in military combat, or rape. Shapiro has found that distressing or disturbing thoughts could be eliminated with the pairing of diagonal upward to and fro eye movements [3]. In a study involving 70 individuals, a procedure that involved the use of various eye movements and the patients' distressing thoughts and images were used to unblock stalled emotional processing. Despite the fact that it is a relatively new treatment, studies have shown that the effectiveness of EMDR is similar to that of the more traditional trauma-focused cognitive behavioral therapy (CBT) in the treatment of PTSD in adults [4]. In addition, EMDR therapy has helped manage previously untreatable cases of PTSD [5].

EMDR is a therapy that influences emotional processing via eye movement, and using the basic principles of game design will influence the user's emotions and memories. Electroencephalogram (EEG) measures the underlying physiological responses to eye movement therapy. Biofeedback can be used to stimulate eye movements toward specific brain states and explore its implications on memory, emotions, and engagement.

Electroencephalography Technology

An EEG reading measures the action potentials occurring on the cortical surface of the brain due to neural activation, thus providing brain activity measurement. Temporal and spatial activities correlate to specific mental states, as listed below:

1. *Delta (1-4 Hz)*: Deep sleep and unconscious processes, such as fatigue or trance
2. *Theta (4-8 Hz)*: Daydreaming, creativity, intuition, memory recall, emotions, and sensations
3. *Alpha (8-14 Hz)*: Cortical inactivity and mental idleness as well as demand of attention
4. *Beta (14-30 Hz)*: Frontal cortex and cognitive processes, decision making, problem solving, and information processing

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EEG studies have found increased frontal and parietal alpha power activities during a racing game [18] and elevated theta activity during long gaming tasks [19]. Nacke et al compared 3 different level design conditions (boredom, immersion, and flow) by measuring the patterns of EEG spectral power [20]. The result has indicated that the immersion-level design elicited more activity in the theta band. Rani et al analyzed 3 levels of intensity for different emotions based on the EEG data obtained using the *Pong* game and anagram puzzles [21]. Sourina et al used EEG signals to continuously assess the emotional state of players and developed the game for stress management called *Pipe* [22]. Using EEG signals, Chanel et al assessed 3 different emotions (boredom, engagement, and anxiety) corresponding to 3 difficulty levels of *Tetris*, and the accuracy increased up to 63% [23]. Ravaja et al showed that different EEG data are triggered by wounding and killing events in a digital console game; for example, wounding resulted in an increase in occipital theta activity [24].

These results motivate us to test the following 2 hypotheses in this study: H1, the beta power will increase with playing the EMDR game and H2, the theta power will decrease with playing the EMDR game.

Methods

Game Design and Development

We designed a video game called *Lifeguard* to induce eye movements, as shown in Figure 1, to create more engaging experience among eye movement processes. During the game play, the players need to stare at the floating targets, which will provoke 4 different eye movement modes, including *right-left, up-down, up right-up left, and down right-down left*.

A player rescues the floating target by clicking on it, and each click will decrease a life buoy number. They must decide if it is the right time to throw the life buoy out to rescue the floating, whereas the rescuing of humans and animals will bring reward points. However, other things, such as fish, will just waste the limited number of life buoys. If they click on other places in the screen, the life buoy will be wasted as well. Different targets will bring different numbers of reward. Some particular targets will bring extremely high reward points, such as a baby and old man, and this randomization will increase the fun of surprise and variation for the whole process of game play. There is also a time limit of 10 minutes for each game session. The game will be over when the number of life buoys becomes zero or the player runs out of time. In addition, the goal of the game is to get maximum possible reward points via rescuing targets within the limit of both life buoy number and time. A summary will show the record of the players in this game session, including reward points and the total number of targets rescued, which can be compared across different sessions or different players.

We finished the design document of *Lifeguard* and collaborated with a game company to do the art and coding work for this game. Meanwhile, we oversaw the whole process. A playable iOS version of *Lifeguard* has been launched, and it can be run on the platform of iPad or iPhone, as shown in Figure 2.

Electroencephalogram Measurement of the Eye Movement Game

To better understand the physiological mechanism behind eye movement, real-time biometric measurement is used to monitor the participants while playing the video game. We recorded brain activity using 64 electrodes during the duration of game play, allowing us to track what eye movements stimulate the brain and what kind of brainwaves are being produced.

Figure 1. Screenshot of *Lifeguard*.

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Figure 2. Playing *Lifeguard* on an iPad.

In particular, we wanted to the compare eye movement game with *Tetris* because a previous study has shown that Tetris can be used for the treatment of PTSD [10]. The experiment was designed to examine if the EMDR-based game will stimulate different measurable brain wave patterns compared with the commercial game *Tetris*. We mapped out the differences in EEG spectral power activity for the alpha, beta, theta, delta, and gamma frequency bands evoked by the 2 games. The version of *Tetris* used herein is from the Apple Store [25].

Experimental Design

We used a repeated-measures within-subject design with game playing as an independent variable in 2 conditions (*Lifeguard* and *Tetris*). Each participant played 2 games in a random order (a sequence of AB or BA) to eliminate sequence effects. The dependent variables included the collected and estimated EEG spectral power.

With the use of electrodes attached on a player's scalp, EEG will determine the electrical impulses generated by the brain during a given sequence. EEG readings obtained real-time workable measures of engagement and emotion corresponding to different sequences represented in the game. Typically, an EEG measures the voltage recorded between the electrodes placed in standard position on the scalp. As shown in Figure 3, we measured brain activity using 64 scalp pin-type active electrodes and with common mode sense active electrode and driven right leg passive electrode that is equivalent to ground electrodes. Each electrode is letter coded to indicate its position when distributed over the head, such as frontal, parietal, temporal, occipital, or central. Electrooculogram and video-oculography are recorded to correct artifacts from eye movements by placing flat-type active electrodes on the lift and above and below the lift eye. The raw EEG signal is captured with the ActiView acquisition software.

Participants

Overall, 11 healthy participants were recruited from the Hong Kong Polytechnic University, and they completed the experiment in the EEG laboratory in the School of Design of Hong Kong Polytechnic University. The participants included 7 women and 4 men aged 24-30 years. All 11 participants are right-handed, and they have experience in playing video games.

Procedure

First, the participants were asked to fill out a pre-experiment questionnaire about their demographic characteristics, such as gender and age, and game experience. Before the experiment, the instructor provided a brief introduction about the experiment and EEG measurement. The participants were then asked to seat in a comfortable sofa, and the electrodes were then attached. The participants were asked to relax for approximately 3 minutes, during which the baseline recordings were obtained. Then, the participants played 2 game sessions each for approximately 7-10 minutes (maximum time) on an iPad with the EEG measurement.

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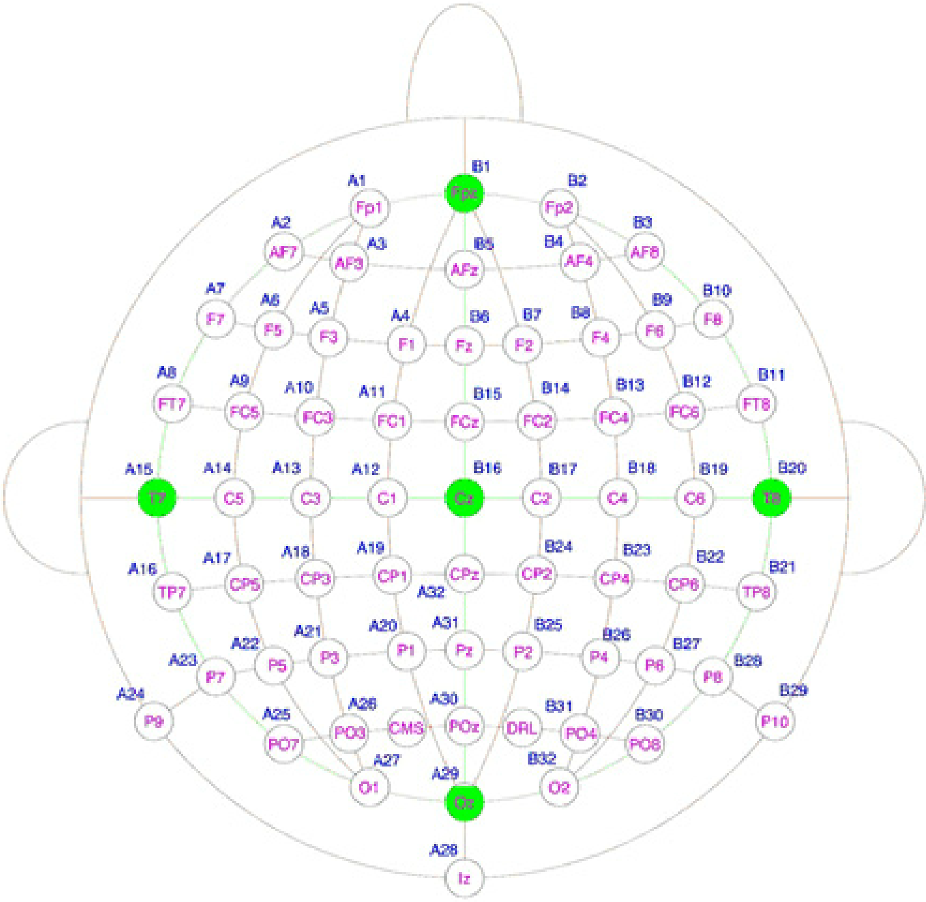
Figure 3. Position of 64 electrodes.



Results

Raw EEG signals were processed using the BESA software (Besa GmbH, Gräfelfing, Germany). The average power estimates were calculated using fast Fourier transformation with the following frequency bands: delta, 1-4 Hz; theta, 4-8 Hz; alpha, 8-14 Hz; beta, 10-30 Hz; and gamma, 30-50 Hz. The spectral power estimates were then averaged for all 64 electrodes for each frequency band.

A series of *t* test was performed to examine the differences across all 5 band power averages with 2 games as independent variables and different frequency bands as dependent variables. As shown in Figure 4, the eye movement game decreased the delta frequency bands, whereas the score of alpha bands was extremely similar. However, as indicated in Table 1, no statistical significance was revealed.

Figure 4. Electroencephalogram frequency of *Lifeguard* and *Tetris* playing.

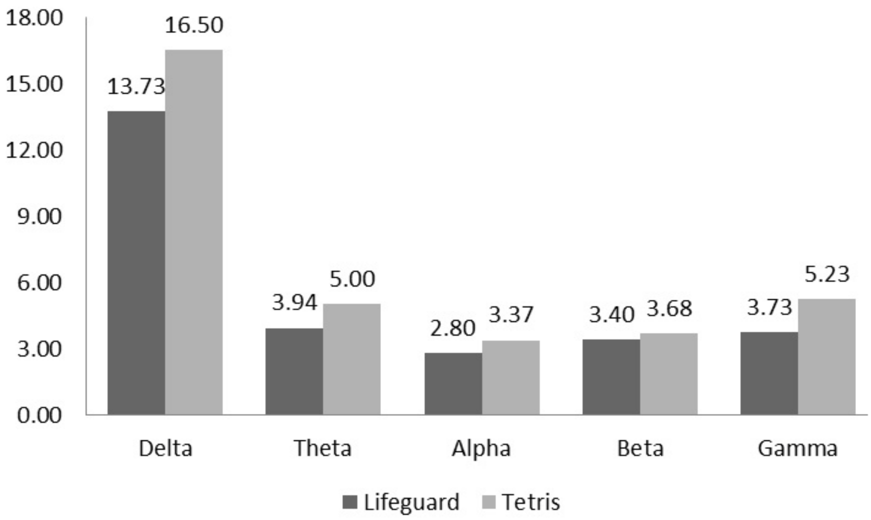


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Table 1. *t* test of electroencephalogram frequency.

Frequency and game	Mean[a]	*t* test	*P* value
Delta		0.60	.57
Lifeguard	13.73		
Tetris	16.50		
Theta		1.06	.32
Lifeguard	3.94		
Tetris	5.00		
Alpha		0.91	.39
Lifeguard	2.80		
Tetris	3.37		
Beta		0.29	.78
Lifeguard	3.40		
Tetris	3.68		
Gamma		−0.86	.41
Lifeguard	3.73		
Tetris	5.23		

[a]Mean: all the values indicate average power calculated.

Discussion

We designed and implemented *Lifeguard* based on eye movements, and the EEG results of the players of this game were compared with those of the players of *Tetris*. However, we did not find a significant difference in the EEG frequency stimulated by playing *Lifeguard* and *Tetris*. Our results did not support H1 and H2. However, we have observed some trends that could be used as a basis for future research.

When interpreting biometric data collected from game playing, it is important to understand the relationship between mental processes and body responses. The players' body is still present in the real world while playing a video game; therefore, it responds to specific in-game elements and external activities, anticipation, or something not otherwise observed. Thus, the physiological response to video games is a many-to-one relationship, wherein one body response may be associated with several mental effects or processes [26]; for example, when recording the biometric data of a player, room temperature, movement, drugs, and noise may influence brain waves and bring contextual bias in the interpretation of the result. Without a higher degree of experimental control, it will be difficult for researchers to make assumptions about the players' mental processes based on their body responses [27].

This study only used *Tetris*, which is a visual space game. For future research, more video games, such as action, puzzle, and shooting games, may be compared with *Lifeguard* to explore their difference. In addition, further studies should be conducted to compare the EEG features of different eye movement modes stimulated by game playing, such as horizontal moving and vertical moving.

The use of games in exploring the relationship between eye movement and brain wave activities can also lead to improved eye movement techniques for existing treatments, such as EMDR, or new techniques to treat other ailments or disabilities.

Acknowledgments

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Conflicts of Interest

None declared.

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Abbreviations

ADHD: attention deficit hyperactivity disorder
CBT: cognitive behavioral therapy
EEG: electroencephalogram
EMDR: eye movement desensitization and reprocessing
PTSD: posttraumatic stress disorder

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Viewpoint

The Untapped Potential of the Gaming Community: Narrative Review

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Abstract

Background: Video gamers are a population at heightened risk of developing obesity due to the sedentary nature of gaming, increased energy intake, and the disruption caused to their sleep. This increases their risk of developing a number of noncommunicable diseases. To date, research seeking to improve health behaviors has focused on developing novel video games to promote behavior change. Although positive results have emerged from this research, large-scale success has been limited due to the lack of transferability to mainstream games and the focus on children and adolescents. The gaming community has a number of unique aspects, which have received comparatively less attention than the development of new video games.

Objective: The purpose of this paper is to highlight under-researched areas that have the potential to encourage positive health behavior among this community.

Methods: A narrative review of the lay and academic literature was conducted to provide context and support to our claims that further research could be beneficial in this area.

Results: Research has found that advertising can have implicit effects on an individual's memories, which could influence later decisions. However, the effect of the exponential growth of in-game advertisements and the brand sponsorship of gaming events and professional gamers have not been explored in the gaming community. The possibility of using advertising techniques to encourage positive health behaviors within games or at these events has also not been explored. Research suggests that virtual communities can be effective at disseminating health information, but the efficacy of this needs to be explored using known community influencers within the gaming community.

Conclusions: This paper has highlighted a number of potential avenues for the development of interventions within the gaming community. Further research must be conducted alongside game developers to ensure that any in-game developed interventions do not deter gameplay and gamers to ensure that potential approaches are acceptable.

(JMIR Serious Games 2018;6(3):e10161) doi:10.2196/10161

KEYWORDS

video games; advertisements; health behavior

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Introduction

Background

Obesity has become a major problem, with an estimated 1.9 billion adults worldwide classed as overweight or obese in 2014 [1]. Furthermore, the growing prevalence of childhood obesity is now described by the World Health Organization as a major challenge of the 21st century [2]. Obesity is linked to an increased risk of developing a number of noncommunicable diseases [3] and is the second largest cause of cancer after smoking [4]. Previous research suggests those with a higher body mass index are at an increased risk of up to 17 different cancers [5-7]. An increased intake of energy-dense foods and increasingly sedentary lifestyles are central to the rise in obesity prevalence [1]. The video gamer population is at an increased risk of developing obesity because traditional gaming has now become a sedentary behavior.

Sedentary behavior is also implicated as an independent risk factor for a number of noncommunicable diseases [3]. Epidemiological studies have found that sedentary behavior is a strong risk factor for the development of endometrial [8,9], breast [10,11], and ovarian [12] cancer in women. In men, sedentary behavior is a strong risk factor for the development of colorectal (*borderline* impact for women) [13] and prostate [14] cancer. Sedentary behavior involves performing activities in a sitting or lying position while using low levels of energy, and it is considered separate and distinct from a lack of physical activity [15]. Sedentary behavior includes leisure, work, and transportation activities, and it is commonly measured by quantifying television viewing, video game use, or general screen time [16,17]. Research suggests that sedentary behavior increases the risk of developing obesity [18-20], with those who watch television for more than 20 hours a week more likely to be affected by obesity compared with those who only watch television for 5 hours or less (25% and 14%). Estimates are similar for the use of computers [21].

Video games have also been found to increase energy intake among healthy males. A randomized crossover study found that despite increased levels of energy expenditure while playing video games (mean energy increase compared with the rest state=89 kJ), this was counteracted by higher levels of energy intake after playing video games, resulting in an energy surplus of 335 kJ compared with those who rested for the same period [22]. Furthermore, video games have been implicated in the disruption of sleep when played before bedtime. Research involving healthy, good-sleeping adolescents (N=21) found that there was a highly significant negative correlation between gaming time and sleep duration ($r=-.92$) [23]. Shorter sleep duration has been associated with an increased risk of weight gain among males, and a higher incidence of obesity was observed in males with shorter sleep duration [24]. Those who play a large number of video games may, therefore, represent an *at-risk* population that could benefit from targeted interventions.

The majority of previous research involving gamers has focused solely on the potential for video games to be used as a medium for health behavior change, either by increasing the knowledge and awareness of health behaviors or by including physical activity within the game itself. A large body of research has explored the potential to develop games to improve health [25-27]. A recent review of systematic reviews found that active video games among children could increase levels of physical activity and energy expenditure. Health education games also have the potential to support diabetes-related behavior and dietary change [28]. However, research in this area has focused on children and adolescents, whereas the average gamer age is 35 years in the United States [29]. Furthermore, it is unlikely that long-standing gamers will be motivated to change their gaming habits from mainstream video games to active or educational video games. Therefore, additional opportunities for interventions targeting gamers should be explored.

Objective

This paper aims to discuss the potential avenues for future research in this area, drawing on the attributes that are unique to the gaming community.

Methods

This paper comprises a narrative literature review. It draws on lay literature to provide context and descriptive detail and academic literature to support the claims that further research could be beneficial in developing this area for health behavior change. This literature was identified through the following electronic databases: Web of Science, MEDLINE, Google, and Google Scholar. The following keywords were used in various combinations: “video games,” “gamers,” “professional gamers,” “gaming events,” “advertising,” “in-game advertisement,” “vloggers,” “forums,” “online communities,” “virtual communities,” “fast food,” and “marketing.” A *snowball method* was also employed, wherein references from relevant papers were reviewed to identify other relevant papers.

This review will refer to both hardcore and casual gamers as *gamers* due to the lack of a universally accepted definition to objectively categorize these 2 groups [30] and the general lack of distinction between the 2 groups in research to date. The term *gaming community* will be used to cover the areas in which gamers interact, such as video games, gaming events, online forums, and video blogs. Gamers are extremely heterogeneous, representing a range of demographic, social, and behavioral groups, and they span international and cultural divides. Understanding the heterogeneity of gamers and their behaviors and influences and subsequently targeting interventions or marketing would provide a rich avenue of research to pursue; however, this aspect is not explored in this review.

Results

Several aspects of gaming that could be utilized to engage gamers in health behavior change, including gaming environments, virtual communities, and community influencers, were identified. These features and their ability to be applied to health behavior change are described and discussed below.

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In-Game Advertisement

Companies use marketing to connect consumers with their products and services [31]. There is a range of marketing strategies and tools that companies can employ to promote their brand, with advertising being one of the more expensive approaches. In in-game advertisement (IGA), companies pay to have their brand promoted within a game itself [32,33]. In 2004, companies spent US $34 million on IGA [34]; this spending grew exponentially to US $3.1 billion in 2011 and was expected to reach US $7.2 billion in 2016 [35]. This can occur in different forms such as posters or billboards within the game environment, food that is consumed by a character, or having a character dressed in branded clothing [36]. However, not all games lend themselves to IGA, and it is often only included if it is seen as congruent with the game. With the rise of mobile gaming, advertisements have also started appearing in apps at the top or bottom of the phone screen or as short video clips between levels [37]. These advertisements can be personalized to the user through the use of metadata collected by search engines, social media companies [38], and mobile apps [39], which is thought to make them more effective at reaching their target audience [40,41].

Research has found that IGAs have a strong effect on our implicit memory. For example, 1 study found that participants who played a Formula 1 video game scored significantly higher on a word-fragmentation task of brand names (that were shown in the video game) than those in a control condition [42]. The authors concluded that these effects on implicit memory could in turn influence later decisions. Research has shown this to be the case for television advertising; for example, studies have shown that television advertising for unhealthy food increases positive attitudes toward junk food in children [43] and increases food consumption and time spent eating food among adults [44]. Interestingly, these studies also found that advertising nutritious food showed an increase in positive attitudes toward healthy food and less consumption of food in general.

In 2007, Ofcom, the communications regulator for the United Kingdom, introduced a ban on television advertisements of high fat, salt, or sugar (HFSS) food or drink products for children's airtime to reduce the exposure of children aged less than 16 years to unhealthy foods [45]. The effectiveness of this ban provided an estimated reduction in children's exposure to HFSS advertisements by 37% in 2009 compared with 2005 [46]. However, with a migration of viewing habits to Web-based providers, children could still be exposed to HFSS advertising. In 2016, a ruling by the UK advertising regulator extended these restrictions to all nonbroadcast media for children aged less than 16 years or that have an audience made up of 25% of children aged less than 16 years [47]. Although a piece of legislation was expected to come forward in 2017 to address this, video games were still not covered, and therefore, individuals were still exposed to IGA. For example, *Wendy's* (a burger chain operating primarily in North America) is set to have an IGA for their *Baconactor* (a 950-calorie burger) on billboards, bus shelters, and television screens within the virtual gaming systems of multiple games spanning Xbox, PlayStation 4, and personal computer platforms [48]. Information on the product claims, "The addition of the product was part of a push to add menu items that appeal to the 18- to 34-year-old demographic and expand late-night sales" [49]. Dynamic IGAs, such as those used by Wendy's, can cost around US $4-12 per 1000 impressions received (1 impression=the advertisement being on screen for 10 seconds). Static IGAs that cannot be changed once the game has been released can cost between US $50,000 and $500,000 [50].

Banning HFSS advertisements in games may be more difficult than with television or the internet, as such a ban cannot be targeted at a certain age bracket and a blanket ban approach may be considered heavy-handed. This ban may also not be possible in certain countries that have laws guaranteeing freedom of speech, such as the United States. However, it may be possible for video games to be utilized in a different way to combat IGA of HFSS. If funds were available, charities (eg, Cancer Research UK or Diabetes UK) could consider counteradvertising and place their own IGA's, which could target people directly with health-promoting messages or information. Within a collaborative context where charities and game developers share values on an approach, content of such premium games could be developed or adverts may be targeted toward health behavior change to influence implicit memory in gamers. This could be a viable alternative when regulation is not an option. Research has shown that gamers develop negative attitudes to advertisements that are intrusive and incongruent with the game, as it reduces their sense of realism [51,52]. There is, therefore, a need for developers willing to take up the challenge to show how positive advertisements may be effectively included in games to support healthy behaviors and choices.

Further Promotional Techniques

Brands have diversified their promotional mix beyond advertisements to target the gamers in other unique ways. Viral marketing techniques utilize the internet and already established social networking services and sometimes community influencers to popularize a brand [53]. *Burger King* teamed up with *Sony Spain* to offer the delivery of fast food to gamers who signed up to play with professional gamers online. After completing a game, the professional gamer would then take the order and it would be delivered to the gamer's door [54]. Viral marketing campaigns have been found to be effective tools for the promotion of a brand [53]. Brands have attempted tie-ins with newly released games by offering discounts and prizes to people that buy their products. For example, with the release of the *Call of Duty: Black Ops III*, gaming prizes including *Double XP* could be won by buying special *Mountain Dew* and *Doritos* products [55]. Research has found that the use of promotions for well-known brands can have a positive impact on its long-term sales prospects [56]. The use of viral marketing and promotions by companies seeking to market their brands cannot be stopped; however, their association with large companies such as *Sony* can be targeted. In recent years, corporate social responsibility has become increasingly important to both the consumer and the company [57]. It can affect the way that consumers evaluate a brand and can act as protection for a company in times of crisis [58,59]. Therefore, the encouragement of collaborative work between health

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researchers, charities, and corporations would help to serve both sides.

Gaming Events

Gaming events where gamers and developers gather to play, demonstrate, and discuss games are an extension of the gaming community. They offer additional opportunities for promoting health messages and engagement with audiences. A number of these events attract the video game community, such as comic book conventions, gaming festivals, and eSports tournaments. These typically feature high numbers of sponsors and promotions for energy drinks, fast food, and other high-calorie foods [60].

eSports are video gaming competitions involving mostly professional gamers that contend for prize money. These events are frequently broadcast on television and streamed live over the internet. The final for the League of Legends (a multiplayer online battle arena video game) 2015 World Championship drew a global audience of 36 million viewers [61], which was greater than the 2016 NBA final that drew 31.2 million viewers [62]. eSports events have a range of brands that are marketing partners and sponsor both the events and teams. This is a further promotional technique to increase brand recognition and generate positive publicity within the gaming community. The energy drink Red Bull, in particular, has a strong brand presence in eSports by sponsoring some of the biggest tournaments, teams, and clubs [63]. Monster Energy drink, along with Papa John's Pizza, sponsors the most successful video gaming team in the world, *Evil Geniuses* [64]. This suggests that these events give advertisers a unique ability to target and engage gamers. Although removing brand investment from these events may be difficult, as with IGA, it may be of significant value to explore promoting advertisements with positive nutrition messages or conducting health and health behavior seminars in the downtime between eSports matches to balance out the effects of other advertisers. In addition, the development of guidelines or regulations for food choice management during these events could encourage organizers to expand the range of food and drink choices on offer. Providing incentives, vouchers, or tokens to eat healthier foods (which could be funded through ticket-pricing adjustments) could also help modify choice, moving to a distinct *nudge* toward healthy eating among this community [65]. Initial work might explore the *appetite* for health marketing at these events and the methods to quantify the potential effects for the video game community.

Community Influencers

Among many communities, there are those who are considered *influencers*—individuals who have a greater amount of influence over members' commitment [66]. Professional gamers have emerged as influencers within the gaming community by becoming the best gamers within their respective gaming genres, and they appear to be styled as celebrities of the gaming community [60]. These professional gamers receive investment from companies and in turn wear clothes with the company's logos for matches, in the same way as active sports such as soccer or tennis. They make videos promoting products and play video games that are live-streamed on the company's website to attract the attention of the game's audience by using the gamer as an advertisement [67]. Celebrities have been found to be effective mediums for advertisements of energy-dense and nutrient-poor food products, both for children [68] and adults [69]. This effect is thought to be due to celebrities conferring an implicit benefit and by establishing positive associations with the brand through the transference of qualities of physical appeal and likeability from themselves to the product [70,71]. Again, the absolute removal of this incentive and investment involved for professional gamers might not be achieved easily, as they are often reliant on sponsorship to support their career [72]. Nonetheless, attempting to harness this influence within the community may help to counterbalance unhealthy advertisements. For example, attempting to use the gamers' influence to create positive attitudes to health behaviors may be a viable option.

Game-related video bloggers (vloggers) have become increasingly popular among gamers. These vloggers post videos of themselves playing games and giving commentary, glitches within games, reviews of games, formal walkthroughs of games, using video games to create films from the content, and *speed runs* of people completing things in the fastest time [73]. An individual known as *PewDiePie* is the most popular vlogger on YouTube with over 54 million subscribers to his channel and was the first YouTube star to reach over 10 billion views; his popularity came from his commentary of video games [73,74]. PewDiePie's popularity offers significant influence with an engaged audience, with reports of increased game sales when a positive video is posted of the game on his channel [75]. This influence has been found to extend to charity fundraising—raising almost $500,000 for *Water Campaign* by encouraging subscribers to donate [76], demonstrating the potential of these influencers to encourage positive behaviors outside of gaming.

The effect of this *influence* among online communities is borne out in research, which suggests that these influencers provide an important role in the social discourse: encouraging discussion and interaction between members, arranging events, and keeping site content up-to-date [77]. Zhang and Dong [78] have suggested that these influencers can have a lot of sway over the opinions of community members but that this is dependent on their ability to engage the community through sociability and the extent of their knowledge and innovation. Therefore, much as with professional gamers, utilizing these community influencers could help to shape opinions on healthy behavior among gamers.

Virtual Communities

The aforementioned online social communities have developed in conjunction with many video games [79]. Individuals use these communities to discuss the game and share ideas and goals without the constraints of geographical location [80]. The most frequent gamers, who tend to play multiplayer and online games, can play with other gamers online for an average of 6.5 hours a week and in person for 4.6 hours a week [81], suggesting that the social aspect of gaming plays an important role for those engaged in these communities. Virtual communities have been found to be effective mediums to disseminate health information. They support and encourage discussion among members and

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can provide places to seek help and emotional support, which can be used to promote behavior change [82,83]. Furthermore, satisfaction with interventions delivered within virtual communities has been found to be significantly higher than that in control conditions [84], although inconsistent results have been found for the effectiveness of moderated virtual communities for behavior change [85]. However, previous research has focused on social networking sites and online patient groups that have typically been set up as interventions for specific studies. Participants in these new communities may therefore not have the same level of trust in the moderator that an already established video game–related community might have. Whether virtual gaming communities are used to discuss health information or if interventions delivered within these communities could promote behavior change needs to be explored.

Research has also begun to investigate the ability of 3-dimensional virtual worlds to act as a more immersive form of online social support [86]. *Second Life* has been studied as one of the most realistic and immersive virtual world's available [87], where people can create and personalize their avatars that interact with each other and the environment. There is some evidence to suggest that when people practice health behaviors in the virtual world, they are more likely to transfer this to real life [88]. The dissemination of health information and encouragement of positive health behaviors within virtual worlds, like Second Life, could, therefore, prompt behavior change, particularly if accompanied by support from other gamers and/ experts in the game [89]. However, there are *massively multiplayer online role-playing games*, such as World of Warcraft and Star Wars: The Old Republic, which offer less realistic worlds and are instead based on fantasy-oriented worlds. Gamers may interact with these games differently with regard to health matters, if at all. Gaining a greater understanding of how these communities approach both the social aspect of gaming and health issues may be important for the future development of interventions for this population.

Discussion

The exponential growth of gaming and its supporting online communities is a trend that continues to grow—followed by advertising investment—presenting an opportunity to engage with a key audience. The research outlined in this paper suggests that gamers are already exposed to advertisements that encourage unhealthy behavior both in games and at gaming events. There is, therefore, a need for policy and interventions to attempt to redress these effects and promote healthy behaviors among this group of individuals.

There are points to consider when conducting further research that could have an influence on the development of interventions to influence health behavior change. First, in recent years, the gender gap in those that play video games has narrowed, with women making up over 40% of the gaming population in the United States and Europe [90,91]. However, research suggests that many of the games that are developed are hypersexualized and directed toward heterosexual males [92]. Therefore, any intervention development should consider the gender split to ensure that it has the widest possible application. In addition, the development of interventions should be mindful of the racist undertones that have appeared in some of the most popular video games, such as Grand Theft Auto [93]. The stereotypical approach to character development could exclude certain groups of gamers who may feel judged. This can also extend to individuals who are obese, as research has found that the obesity stigma is not conducive to reducing levels of obesity [94]. Therefore, there is a need to be mindful of any stereotypes when developing interventions.

Moreover, there should be more investigation about the distinction between hardcore and casual gamers and how future interventions could influence each group. Hardcore gamers have been described as those that dedicate a large portion of their leisure time to gaming in comparison with casual gamers [95], and so they may be considered more *at-risk*. However, there is currently no universal definition to objectively categorize the gamer type. A move toward better defining groups of gamers would enable studies to explore whether interventions should target differences in how these groups play games as well as the type of game and other behavioral factors. However, these issues were not explored and were beyond the scope of this review.

Furthermore, although we know that the IGA revenue has risen exponentially in the past decade [35], we do not know how much of this has been spent on the advertisement of HFSS food and drink products. Future research should investigate the occurrence of HFSS advertisements not only within video games but also in the wider areas related to video games, such as gaming events and gaming vloggers. This will give an indication of the diversification of the advertising strategy employed by these companies.

In summary, research to date has focused on the development of games specifically designed to change health, but more could be done to explore opportunities within existing online communities and virtual worlds and utilizing known influencers and methods of advertising to this group. Research in all these areas, conducted in a coordinated way with gamers, vloggers, and game developers, would offer any interventions their best chances of success.

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Conflicts of Interest

None declared.

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Abbreviations

IGA: in-game advertisement
HFSS: high fat, salt, or sugar

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Original Paper

Web-Based Immersive Patient Simulator as a Curricular Tool for Objective Structured Clinical Examination Preparation in Surgery: Development and Evaluation

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Abstract

Background: Objective Structured Clinical Examination is a standard method of testing declarative and process knowledge in clinical core competencies. It is desirable that students undergo Objective Structured Clinical Examination training before participating in the exam. However, establishing Objective Structured Clinical Examination training is resource intensive and therefore there is often limited practice time. Web-based immersive patient simulators such as ALICE (Artificial Learning Interface of Clinical Education) can possibly fill this gap as they allow for the training of complex medical procedures at the user's individual pace and with an adaptable number of repetitions at home. ALICE has previously been shown to positively influence knowledge gain and motivation.

Objective: Therefore, the aim of this study was to develop a Web-based curriculum that teaches declarative and process knowledge and prepares students for a real Objective Structured Clinical Examination station. Furthermore, we wanted to test the influence of ALICE on knowledge gain and student motivation.

Methods: A specific curriculum was developed in order to implement the relevant medical content of 2 surgical Objective Structured Clinical Examination stations into the ALICE simulator framework. A total of 160 medical students were included in the study, where 100 students had access to ALICE and their performance was compared to 60 students in a control group. The simulator performance was validated on different levels and students' knowledge gain and motivation were tested at different points during the study.

Results: The curriculum was developed according to the Kern cycle. Four virtual clinical cases were implemented with different teaching methods (structured feedback, keynote speech, group discussion, and debriefing by a real instructor) in order to consolidate declarative and process knowledge. Working with ALICE had significant impact on declarative knowledge gain and Objective Structured Clinical Examination performance. Simulator validation was positive for face, content, construct, and predictive validity. Students showed high levels of motivation and enjoyed working with ALICE.

Conclusions: ALICE offers Web-based training for Objective Structured Clinical Examination preparation and can be used as a selective didactic intervention as it has positive effect on knowledge gain and student motivation.

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KEYWORDS

immersive patient simulator; simulator-based curriculum; Objective Structured Clinical Examination; artificial learning interface

Introduction

OSCE (Objective Structured Clinical Examination) is a well-established method used in clinical education. OSCE aims to simulate clinical scenarios to test different core competencies such as physical examination, communication, clinical reasoning, medical interventions, and knowledge of medical procedures [1]. In each OSCE station, students are given an assignment that tests at least one part of a predefined core competency. Performance is evaluated in an individual assessment by an experienced clinical physician.

Effective preparation for an OSCE requires learning and repetition of both declarative ("what to do") and process ("how to do it") knowledge. Less complex medical procedures such as resuscitation are usually trained on mannequin simulators [2]. More complex procedures such as clinical decision-making and workflows in diagnosis and therapy require small group training on standardized patients in a simulated OSCE. However, simulation of a complex OSCE situation with tutors, doctors, and standardized patients is resource intensive. Hence, OSCE simulation of complex procedures to prepare for the exam is often not part of the curriculum or occurs only with limited practice time. Since the aim of OSCE is to prepare students for future clinical work, it is desirable that they are given the opportunity to train for the OSCE without time pressure and limits to the number of repetitions before they enter the exam.

Immersive patient simulators (IPS) can potentially fill this gap. IPS are Web-based software programs which allow repetitive training of medical procedures in a virtual environment [3]. With IPS, students can practice complex medical procedures at their own individual pace and with a suitable number of repetitions, even on their computers at home. In a recent study, we developed a proprietary IPS, ALICE ("Artificial Learning Interface of Clinical Education"), and proved it had a positive impact on clinical decision-making and student motivation [4].

In this study, we wanted to develop a simulator-based curriculum that imparts both declarative and process knowledge to prepare students for a real OSCE station. In the next step, we aim to implement this curriculum and the necessary features into ALICE and validate the new ALICE version. Finally, in order to test the hypothesis that ALICE is a useful tool for effective OSCE preparation, we wanted to measure students' knowledge gain when working with ALICE and test the acceptance of this educational tool.

Methods

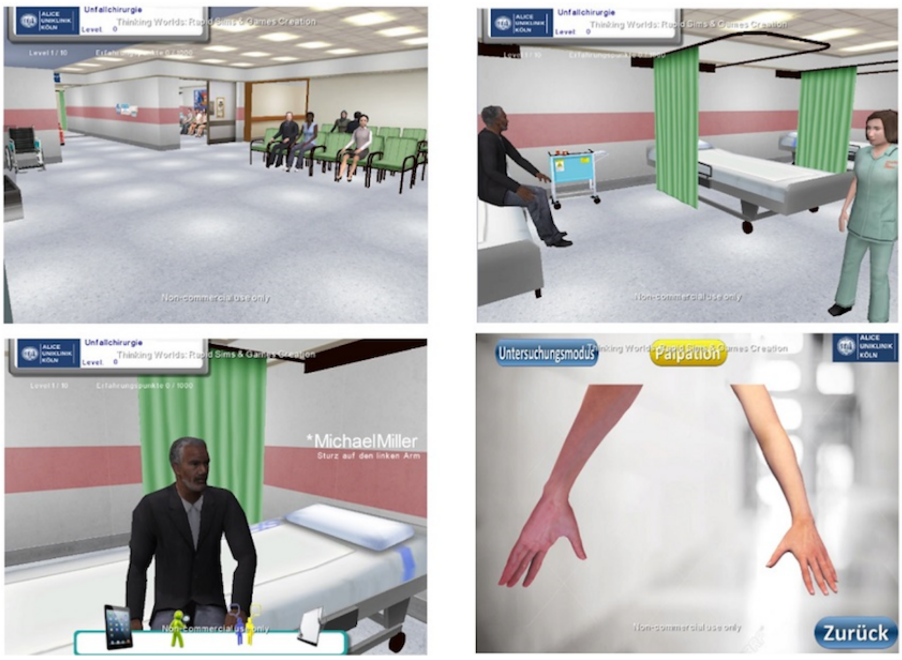
Adaption of Medical Content for ALICE

For this experiment, we chose a classic surgical OSCE station from trauma surgery. It presents patients with a trauma diagnosis (fracture of distal radius) in different clinical cases.

The underlying disease was added to the ALICE simulator framework as a blueprint. The creation of medical content and programming of additional ALICE features were completed according to the steps of Kern's curriculum planning cycle [5].

The design and technical realization of ALICE have previously been described by our group [6]. In short, ALICE is a Web-based immersive patient simulator which allows students to navigate through a virtual "game like" environment from a first-person perspective (Figure 1).

Figure 1. Impressions of ALICE (Artificial Learning Interface of Clinical Education) where students navigate freely and treat virtual patients.



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ALICE simulates a treatment room with a simulated patient. The user can interact with the virtual patient and additional non-player characters such as nurses and other doctors. The simulator starts with a short introduction teaching the user basic simulator controls and usage of the simulator. The user is able to freely interact with the environment and treat the virtual patient. The user is free to choose between all available tests and there is no restriction on specific or medically indicated tests. When the student chooses an examination not medically indicated, the test shows a normal finding. The simulation ends when the student chooses a diagnosis and initiates the necessary treatment. ALICE stores the students' behavior at the server level, logging students' decisions.

Group Distribution and Study Design

Participants in the study were 160 medical students. Participation was on a voluntary basis without any financial compensation. The study group was comprised of 100 students and the remaining 60 students were allocated to the control group. The study was approved by the Educational Committee of the Medical Faculty at the University of Cologne. The Institutional Review Board was informed and there were no objections. The impact of ALICE on OSCE performance was tested using a trauma case examined by 100 students. In the first stage of the test, students answered 11 multiple-choice questions (MCQs). They then participated in a real OSCE. The correct results of the MCQs and OSCE were not revealed to the students at this point. In the next stage, the students worked with the simulator (ALICE), after which they repeated the MCQ questionnaire and the OSCE with the same clinical scenario as before (Figure 2). The correct results were then revealed and discussed in a peer-to-peer debriefing and with an experienced doctor.

The control group consisted out of 60 students who prepared for the OSCE without ALICE. All students passed the study completely without any drop outs.

Validation of ALICE

Declarative knowledge was tested by comparison of students' pre- and postsimulator performance on the MCQs. Process knowledge was tested by comparison of their pre- and postsimulator OSCE performance.

Process knowledge was measured on two different levels: (1) comparison of treatment of virtual patient 1 versus virtual patient 4 in the study group and (2) comparison of pre- and postsimulator OSCE performance. The following parameters were defined: correct diagnosis, correct therapy, and correct workflow in anamnesis and diagnostics. These workflows were designed as a blueprint reflecting the "optimal" workflow suggested by 2 independent senior surgeons.

Validation of ALICE's new features and curricular content was tested on different levels according to the "Consensus guidelines for validation of virtual reality surgical simulators" (Table 1) [7].

Face validity was determined by descriptive analysis. Students were asked to judge the degree of resemblance between ALICE and the real OSCE situation. Content validity was defined as the degree to which the system covers the subject matter of the real activity. It was examined by comparison of ALICE performance in the fourth case and with OSCE performance of the control group. Impact of previous knowledge as a degree of discrimination between the different experience levels was tested using a subgroup comparison between students up to third study year and students in fourth year or higher. Predictive validity as sign of impact on future performance was tested by comparison between the OSCE and control group.

Figure 2. Group distribution of participants; 100 students used ALICE and were compared to a control group with 60 students. MCQ: multiple choice question; OSCE: Objective Structured Clinical Examination.

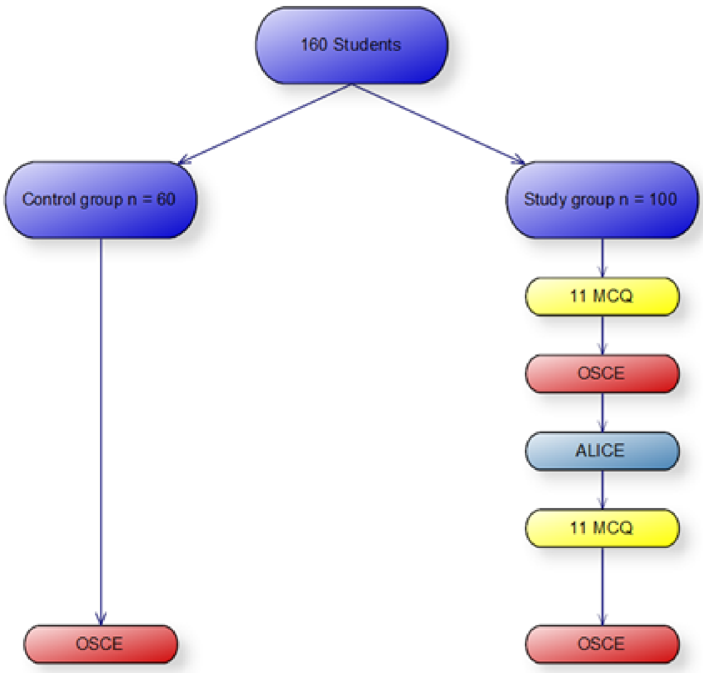

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Table 1. Processes used to test validity of ALICE.

Quality and validity	Method
Knowledge gain	
Declarative knowledge	Comparison: pre- and post-MCQs[a]
Procedural knowledge	Comparison: pre- and post-OSCE[b]
ALICE[c] validity	
Face validity	Similarity study and real activity
Content validity	Comparison: ALICE - OSCE performance
Construct validity	Comparison: 3rd year and 4th year students
Predictive validity	Comparison: OSCE study and control group

[a]MCQ: multiple-choice question.
[b]OSCE: Objective Structured Clinical Examination.
[c]ALICE: Artificial Learning Interface of Clinical Education.

Student acceptance and their opinion about the effectiveness, applicability, and impact on motivation were determined by means of a questionnaire using a (forced choice) 6-point Likert scale (1=extremely satisfied, 2=very satisfied, 3=somewhat satisfied, 4=somewhat dissatisfied, 5=very dissatisfied, 6=extremely dissatisfied).

Data were analyzed with the SPSS Statistics Version 25 (IBM Corp, Armonk, NY, USA) for Windows (Microsoft Corp, Redmond, WA) and Microsoft Excel Version 2013 for Windows (Microsoft Corp, Redmond, WA). Group comparisons were conducted using *t* tests and *P* .05 was considered statistically significant.

Group Distribution

The participants in the study were 160 medical students (31 males, 129 females; mean age 27 (SD 2.5) years, age range 21-34 years) who participated in the study on a voluntary basis with no financial compensation. All students were in the clinical phase of their studies (up to third study year n=57; fourth study year and above n=103) and had passed the first medical exam after 2 years of study. All students were recruited at the University Hospital of Cologne. Students worked on all 4 clinical cases. ALICE was accessible one day before the OSCE.

Results

Adaption of Medical Content for ALICE

ALICE's content was extended by adding diagnostic procedures for trauma patients. Four clinical cases were presented in a firm sequence according to the curricular demands of the specific curricular needs (Table 2). All students worked on all four cases. The framework of medical content was based on the national learning objectives catalogue.

The learning goals were defined and are summarized in Textbox 1.

Table 2. Clinical cases added to ALICE for this study.

Patient number	Trauma	
	Diagnosis	Therapy
1	Distal radius fracture (Colles)	Conservative
2	Distal radius fracture (Smith)	Reposition and surgery
3	Distal radius fracture (Colles)	Reposition and surgery
4	Distal radius fracture (Colles)	Conservative

Textbox 1. Learning goals for Objective Structured Clinical Examination (OSCE) intervention.

After working with ALICE, students should:

- know the underlying basics in anatomy, physiology, pathophysiology and surgery
- assign specific symptoms to corresponding diseases
- identify the symptoms of virtual patients that are specific to a given disease
- weigh pathological findings and bring them into the clinical context
- demonstrate correct workflow in diagnostic and therapeutic decisions (clinical reasoning)
- make the correct diagnosis and choose the correct therapy

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Educational Goals

The simulation itself covers different *teaching methods*. ALICE starts with a short animation which covers simulator usage. The user is asked to explore the surroundings and familiarize themselves with their avatar in the virtual world. After treatment of the first virtual patient, the user is given *structured feedback* and a *keynote speech* from the virtual instructor. These 2 methods allow teaching of both declarative and process knowledge. After finishing the cases, students first have a *group discussion* with other students after which they are finally *debriefed* by a real instructor on the educational level of a medical doctor. These two methods consolidate declarative and process knowledge.

Cognitive Engagement was designed according to the ICAP framework (Interactive, Constructive, Active, and Passive) [8]. Working with the simulator puts students in an active learner role and finding the right diagnostic and therapeutic workflow is constructive. Virtual instructors accompanied the students during their cases in the sense of a virtual cognitive apprenticeship. Instructors reduced their support step-by-step according to the number of correct clinical decisions and correct diagnoses made by the students.

Evaluation

Declarative Knowledge

The influence of simulator use on declarative knowledge was measured by comparing the students' results in the pre- and postsimulator questionnaire for the 100 students in the study group. The number of correct answers increased significantly between the pre- and postsimulator questionnaires. The mean scores for the pre- and postsimulator questionnaires were 7.1 (SD 1.1) and 9.14 (SD 0.8; *P*=.009) respectively (Figure 3). Therefore, working with ALICE had a positive impact on declarative knowledge.

Process Knowledge

Students significantly increased their performance from case 1 to case 4 on all 3 indicators of process knowledge, namely correct diagnosis, treatment, and diagnostic pathway (*P*=.002). Therefore, working with ALICE had a positive impact process knowledge (Figure 4).

The effect of ALICE on OSCE performance was tested by comparing performance on the trauma OSCE before and after working with ALICE (Figure 5). Again, working with ALICE led to a significant increase in process knowledge (*P*=.004).

Face Validity

In a descriptive questionnaire, students judged the degree of resemblance between simulated OSCE in ALICE and the real OSCE situation. As shown in Figure 6, most of the students supported the hypothesis that ALICE can prepare for OSCE as it represents a virtual OSCE situation.

Figure 3. Increase in multiple-choice question (MCQ) scores showing working with ALICE had a positive impact on declarative knowledge.

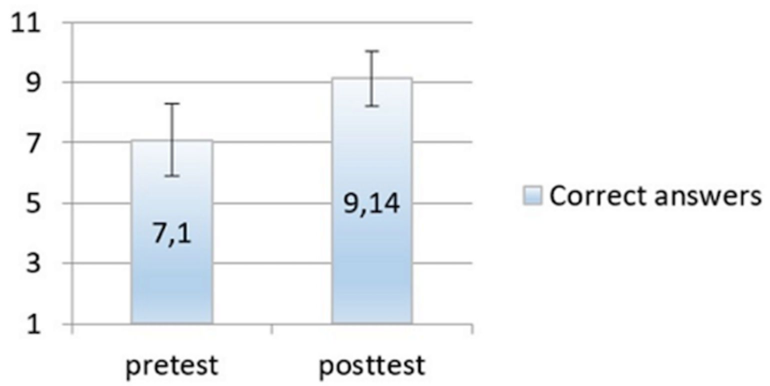

Figure 4. Working with ALICE had a positive impact on students' process knowledge (Y axis shows number of students).

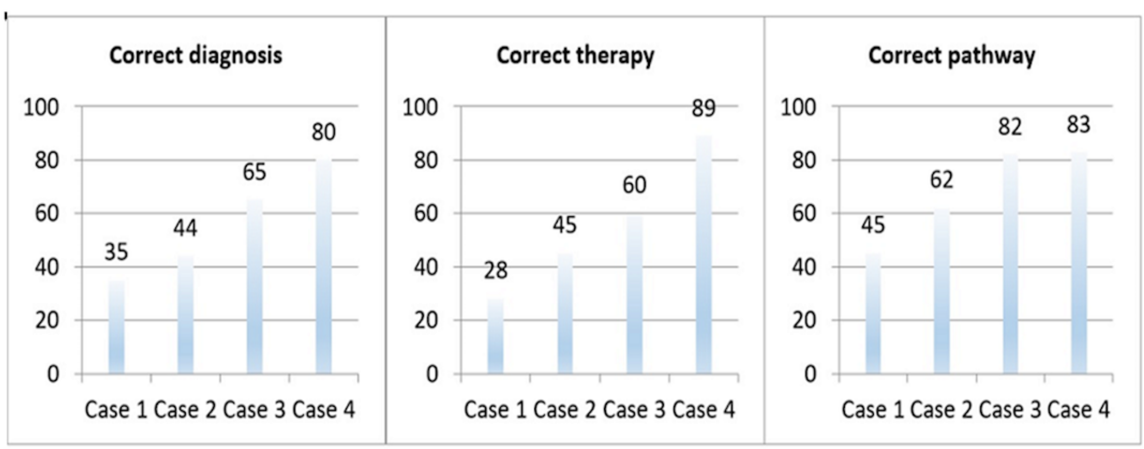

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Figure 5. Working with ALICE led to a significant increase in process knowledge (Y axis shows number of students).

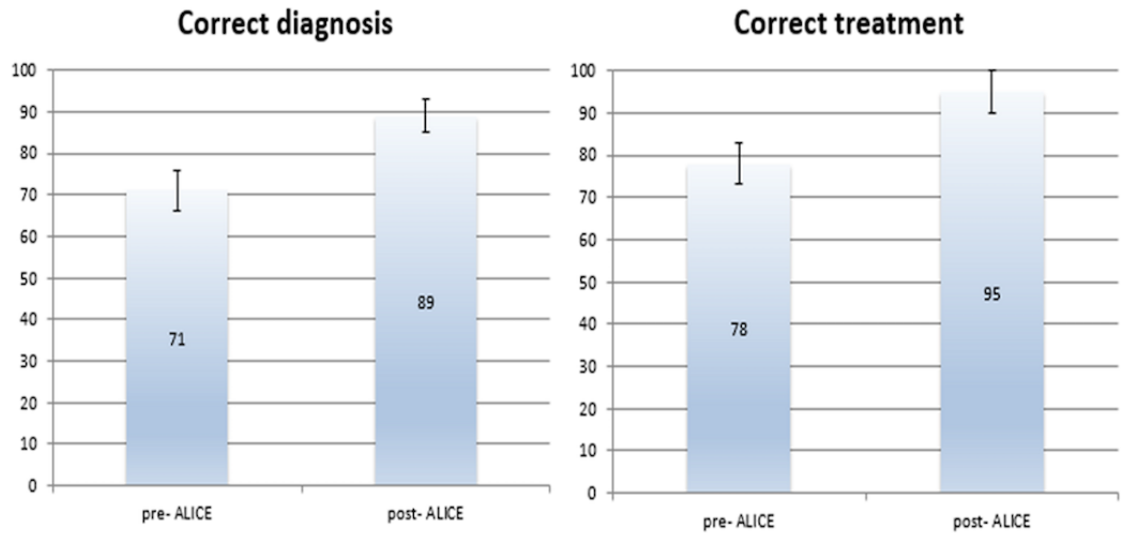
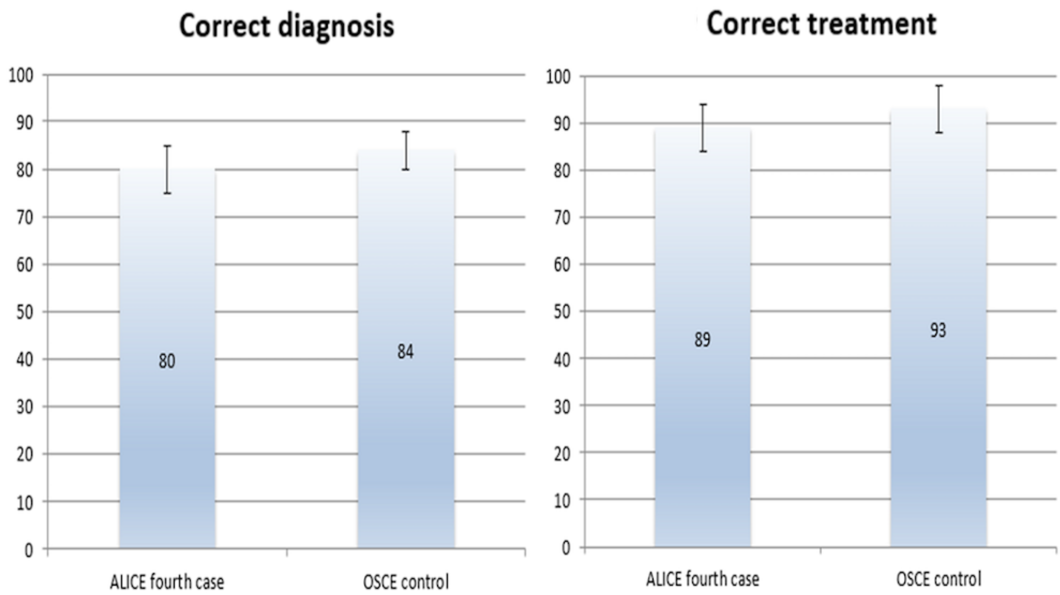


Figure 6. Comparison of ALICE performance in the fourth case and Objective Structured Clinical Examination (OSCE) performance of the control group (Y axis shows number of students).



Content Validity

Comparison of ALICE performance in the fourth case and OSCE performance of the control group revealed, that there was no difference (P=.45) between these groups, proving that there is positive content validity (Figure 6).

Construct Validity

Students in their eighth semester and above performed significantly better in finding the correct diagnosis (mean correct diagnosis 94 [SD 6] vs 78 [SD 4]; P=.04) and correct treatment (mean correct treatment 98 [SD 7] vs 84 [SD 6]; P=.03) in the post-ALICE OSCE compared to the younger students. Therefore, ALICE also had positive construct validity.

Predictive Validity

Comparison of post-OSCE performance in the ALICE group and OSCE performance in the control group revealed no statistical difference between the two groups. Therefore, ALICE has positive predictive validity as it is comparable to conventional OSCE preparation (mean correct diagnosis 89 [SD 5] vs 84 [SD 11]; P=.42 and mean correct treatment 95 [SD 7] vs 93 [SD 8]; P=.56).

The questionnaire data also revealed a high level of student motivation when working with ALICE. Students enjoyed using ALICE and recommended working with such a simulator to prepare for an OSCE. They felt they learned new topics and demanded more interactive content in their curriculum. The majority of the students would use such a simulator frequently and believe that IPS can help prepare them for future work. The overall impression of the simulator was positive. Interestingly, students showed a normal relationship with technology as the proportion of casual users to power users (students that have computers as a hobby and use them every day) was normal (Figure 7).

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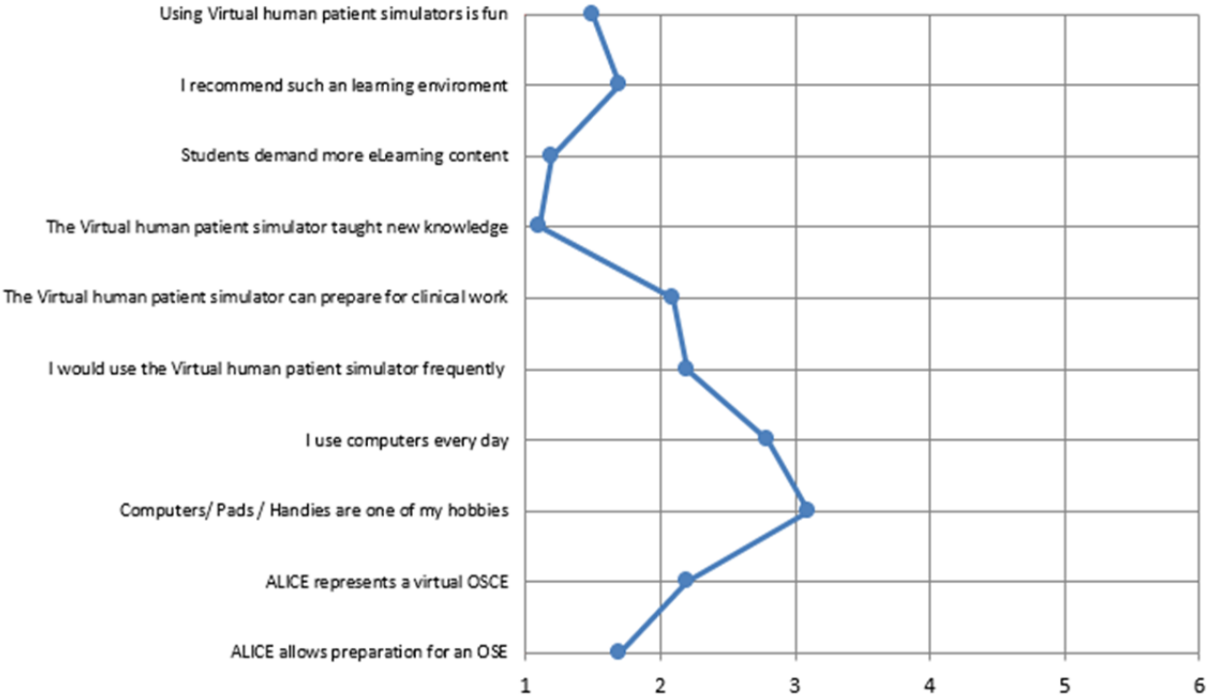
Figure 7. Likert scale (1=extremely satisfied, 2=very satisfied, 3=somewhat satisfied, 4=somewhat dissatisfied, 5=very dissatisfied, 6=extremely dissatisfied) revealed that students felt that ALICE represented a virtual Objective Structured Clinical Examination (OSCE) situation and can help them prepare for an OSCE.



Discussion

Principal Findings

The current study reveals that ALICE is a suitable tool for OSCE preparation. It showed that ALICE has validity (content, construct, and predictive) and leads to a positive impact on knowledge gain. It is inevitable that each modification of such a simulator requires internal validity testing as major changes may affect the effect of such a curricular intervention.

ALICE was designed as a low-cost 3D immersive framework which makes it possible to add different clinical cases in a Web-based scenario with learning that is not time or location dependent. This enables learning at the individual's own pace and with the number of repetitions appropriate for them. Differences in knowledge levels can be evened out and future performance can potentially be raised. However, IPS can only be used as a support for a real OSCE training in terms of a blended learning concept since the degree of reality created by these simulators nowadays is not yet of suitable quality.

Moreover, IPS are limited to simulating clinical decision-making based on defined guidelines or clinical blueprints. In this current feasibility study, we used a comparatively simple OSCE station, namely interpretation of X-rays and a limited number of possible clinical decisions enables a steep learning curve [9]. More complex scenarios, however, are technically possible [10] but their impact on OSCE performance has not yet been proven for these modules. Furthermore, these educational tools are often used as an additional tool for preparation. A study that compares students who used ALICE exclusively for preparation of a complex case and students who prepared with conventional learning methods is desirable and part of future studies. However, the current study reflects reality, as most learners do not rely on only one knowledge source when preparing for an examination.

ALICE shows a positive impact on learners' motivation and both their declarative and procedural knowledge. However, these findings may be influenced by the fact that participation in this study was on a voluntary basis which is known to possibly bias the result as motivated students more often agree to participation than less motivated students [11]. It is important to note that learners have different learning styles and thus not all learners are equally responsive to this educational tool [12]. Hence, the results cannot be generalized for all students.

Although ALICE stored user data, there are little information about the time spent on the simulator and the number of repetitions. ALICE logged the decisions and corresponding time points, however there are no information about students' behavior like breaks, restarts, or distractions. There was no "full logging" of students' behavior such as "time logged on," IP address etc as these program algorithms would require routines similar to spyware, and such implementation was out of the question. Therefore, the influence of number of repetitions and time spent on ALICE cannot be answered in this study.

Embedding a simulator such as ALICE in an educational environment requires thorough curricular planning and subsequent implementation of the curriculum into the simulator. This initial investment pays off once the simulator can be used as an alternative to established teaching methods with high running costs. The current student generation puts high requirements on the quality and motivation of their education [13]. Motivation is known to have a strong effect on knowledge gain [14]. ALICE supports motivation by offering exploration of an immersive world with freedom of choices and treatment

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of the user's own virtual patients [15]. These factors promote experience of autonomy and competency which can directly affect intrinsic motivation [16]. Extrinsic motivation was enhanced by applying features that are commonly used in video games such as reward systems (badges, points, rank), continuous feedback, and leader boards for students [17]. The use of IPS for psychomotor or communicative learning goals is already described in literature and its effect on knowledge gain in these settings is still not proven. Adding these competences to the ALICE framework is part of future studies.

ALICE was designed to cover all qualities of the ICAP framework: Interactive, Constructive, Active and Passive. Hence ALICE promotes not only knowledge gain but also influences students' intrinsic motivation [18]. However, ALICE is most effective when used in a blended learning context as the group discussion is highly interactive and this is thought to have a positive effect on learners' performance [19].

Conclusion

ALICE is a valuable tool for teaching declarative and process knowledge in a Web-based setting. It shows positive impact on knowledge gain and student motivation and therefore enriches the toolbox of didactic methods for OSCE preparation.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1

ALICE - Artificial Learning Interface for Clinical Education.

[MP4 File (MP4 Video), 113MB - games_v6i3e10693_app1.mp4]

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Abbreviations

ALICE: Artificial Learning Interface of Clinical Education
ICAP: interactive, constructive, active, passive
IPS: immersive patient simulators
MCQ: multiple choice question
OSCE: Objective Structured Clinical Examination

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Original Paper

The Modification of Vital Signs According to Nursing Students' Experiences Undergoing Cardiopulmonary Resuscitation Training via High-Fidelity Simulation: Quasi-Experimental Study

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Abstract

Background: High-fidelity simulation represents a primary tool in nursing education, especially when hands-on practical training is involved.

Objective: We sought to determine the influence of high-fidelity clinical simulation, applied during cardiopulmonary resuscitation (CPR) training, on blood pressure, heart rate, stress, and anxiety levels in 2 groups of nursing students. One group had experience in health contexts, whereas the other group had none.

Methods: We performed a quasi-experimental study. Data were collected between May and June 2015 and included measurements of all the resting values, before and after participation in CPR clinical simulations regarding the 2 groups of university students (ie, with and without experience).

Results: An increase in vital signs was observed in students after participating in a clinical simulation scenario, especially the heart rate. In all students, increased stress and anxiety levels were observed before the first simulation case scenario. Also, in all study groups, a decrease in vital signs, stress levels, and anxiety was observed throughout the study.

Conclusions: Participation in high-fidelity simulation experiences has both physiological and psychological effects on students.

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KEYWORDS

high-fidelity simulation training; nursing students; vital signs; stress; anxiety.

Introduction

Over recent years, the value of structured training for education in cardiopulmonary resuscitation (CPR) has increased. Furthermore, according to the European Resuscitation Council (ERC), the probabilities of survival depend on 3 related factors: the application of the chain of survival, updates on recommendations and guidelines, and training in vital support techniques [1]. In this sense, the ERC set down the basis for CPR training in their recommendations made in 2010 [2],

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placing a special emphasis on the fact that training programmes should adapt to the demands of the environment, to the role of those who intervene, and to the probability of a specific event taking place. Nonetheless, and as acknowledged by the ERC, certain gaps remain in the evidence surrounding educational models for the acquisition and maintenance of competencies in advanced cardiopulmonary resuscitation [3]. In parallel, the training of health professionals in CPR has undergone an exponential increase over the last twenty years, due to new teaching methods based on high-fidelity clinical simulation (HFCS). This is defined by the International Nursing Association for Clinical Simulation and Learning as the context in which simulation takes place and which can vary in length and complexity, according to the objectives sought [4]. The teaching methods involved vary widely, as they can be based on the use of basic simulators for airway training, vascular canalization, and electrical therapies, or involve the development of high-reality or high-fidelity simulation environments. Thus, students can benefit from key features, such as the possibility of integrating all the nursing competencies related to caring for critical patients (ie, teamwork, leadership, communication, reflection,) within a safe and realistic environment. This may be beneficial both for students as well as for patients by avoiding confidentiality problems, shortening learning times, and increasing the level of self-confidence and satisfaction. This also enables the re-creation of rare, but critical, pathological processes, the application of protocols, and the structured evaluation of competencies in critical patients [5-9].

Clinical simulation scenarios, as a teaching method employed in the training of health professionals, facilitate objective teaching models, which otherwise would be limited by ethical, social, administrative, and legal parameters [10]. Nonetheless, simulation-based education presents several disadvantages, including the difficulty faced by certain students when they are to face real clinical contexts appropriately as they often treat patients distantly, or as if it were a game. Furthermore, this approach requires more significant investments, equalling a greater burden for students and teachers, and may have unwanted emotional effects on students, producing anxiety and stress, which have negative correlations for the results of CPR training. Also, several studies have described a lack of confidence, transfer of experienced emotions to the simulation environment, as well as a lack of evidence compared with traditional methods [7,11-14].

Previously, critical care residents under HFCS training increased their heart rate (HR), although not their blood pressure (BP), and their state anxiety was maintained under low anxiety levels, showing differences between men and women [15]. To the authors' knowledge, there is a lack of research addressing the vital sign changes according to student nurses' experience undergoing cardiopulmonary resuscitation training via HFCS. Our objective, based on our research on stress during high-fidelity simulation [14], was to determine the influence of this methodology on physiological parameters (ie, BP and HR) as activators of the sympathetic autonomous nervous system, as well as on psychological aspects (ie, stress and anxiety), in 2 groups of nursing students (with and without experience) in a CPR training programme. Our working hypothesis was that the participation of nursing students in high-fidelity simulation scenarios increases the levels of stress, anxiety, and vital signs for all types of health care students, as well as for those with, and without, experience.

Methods

Design

A quasi-experimental study was performed with measurements of all the variables at baseline, before, and after participation in standardized clinical simulation experiences during the 2014 academic year at the Comillas Pontifical University (San Juan de Dios School of Nursing and Physical Therapy of Madrid, Spain). The students were divided into 2 groups: one group had experience in health contexts, while the other group did not.

Participants

The sample comprised 107 students out of a total of 120 who were enrolled in the subject "Physiopathology of the Critical Patient and Vital Support." Participation in the study was voluntary, and all students were informed of the educational nature of the research, including the fact that this would not affect the course evaluation. The inclusion criteria consisted of students enrolled in the previously cited subject and who were in their second year of the nursing degree program taught by the Comillas Pontifical University according to the current recommendations of the European Council in Resuscitation during the 2014 academic year [2]. We excluded students who had taken more caffeine than the average (in relation to the effect on their resting values) or who were under the effects any drugs affecting the central nervous system or the cardiovascular system (benzodiazepines, antidepressants, beta-blockers or flu vaccines), as well as those who did not wish to participate [14].

Ethical Considerations

All students signed the informed consent for participating in the research study. Furthermore, the anonymity of participants was guaranteed, as well as that of the data obtained and its safeguarding. Before commencement of the study, the corresponding ethical-legal permissions for performing the study were obtained, as well as the official approval of the project on behalf of the Research Committee from the Nursing School of the Comillas Pontifical University.

Data Collection

The research took place at the Unit of High-fidelity Simulation in Nursing Care at the University School of Nursing and Physiotherapy. For both the invasive procedures and for providing immediate feedback to students regarding their interventions, a mannequin capable of simulating physiological responses was used. The study was performed during the 2014 academic year, with data collection taking place between May and June 2015. It was planned in 3 successive phases as described in the following.

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Textbox 1. Phase II physiological and psychological baseline parameters.

- Heart Rate (HR) and Blood Pressure (BP): For all students, the basal parameters of HR and BP were measured via 3 measurements, calculating the mean with a certified and approved tensiometer (Omrom M3-HEM-7200-E2; Omron Health care Europe BV, Hoofddorp, Netherlands) and a Nonin Onyx Vantage 9590 pulsioximeter (Nonin Medical, Inc, Plymouth, MN, USA), following the recommendations of the European Hypertension Society [18].
- Anxiety: This was determined by using the state-trait anxiety questionnaire by Spielberger [19] using the available translation and adaptation to Spanish [20]. This self-administered questionnaire consists of 2 parts: (1) for state anxiety (20 items) and (2) for trait anxiety (20 items), showing the Cronbach alpha coefficient range (.89-.95) for state anxiety and (.82-.91) for trait anxiety.
- Stress: Perceived stress was determined using a Visual Analogical Scale (VAS), where 0 is no stress and 10 is the greatest imaginable stress, similar to the analogical scales used by Girzadas et al [21] and Lima et al [22]. Indeed, the VAS has shown adequate construct validity in clinical environments in order to highlight differences in stress levels between two groups, showing acceptable correlations between the VAS and the anxiety domain (r=.66), depression domain (r=.45) and total score (r=.65) of the Hospital Anxiety and Depression Scale (HADS), and similar correlations with other tools applied to evaluate aspects of psychological distress, such as the Perceived Stress Scale (r=.64-.71) [23,24]. In addition, a test-retest reliability coefficient of .83 was reported for the perceived stress VAS [25].
- Age and gender: This quantitative variable was modified to a qualitative variable by grouping data into two intervals—younger than 25 years and older than 25 years.

Phase I involved standardized theoretical-practical training. Participants received a 20-hour theoretical and practical training course in Vital CPR, following the recommendations of the ERC 2010. The course took place in a simulation environment of medium fidelity for the acquisition of competencies in teamwork, coordination, airway management, cardiac massage, electrical therapies, and the administration of medication. Phase II called for the familiarization, preparation of the simulation case scenario, and the measurement of basal variables. At the onset of the standard training period, the students received a workshop for familiarization in high-fidelity simulation environments where they were able to practice on a high-fidelity simulation mannequin with physiological responses (Meti-man, CAE-LINK, Sarasota, FL, USA). One week before, the case was sent to students together with the patient history, the teaching objectives of the simulation and the supporting documentation based at best evidence practice, following the recommendations by Wilford and Doyle [16] and Lioce et al [17] for the design of simulation experiences. All students were presented with the case of a patient aged 67 years, with heart failure. The patient was in a stable condition and had been admitted to a hospitalization unit. The patient could evolve to 3 stages according to the actions and care of the team: improvement, worsening, and cardiorespiratory arrest. All participants were divided into 2 work groups based on their experience in health environments. In Group 1 the students had no experience in real health care environments. In Group 2 the students had experience in real health care environments (eg, emergency technicians, lifeguards, nursing assistants, and radio-diagnosis technicians). Once the groups were formed, they were distributed into smaller groups of 4 students, and the roles were explained (the students were not notified of their specific role until the moment they entered the simulation). One month earlier, the measurement of the following physiological, as well as psychological resting values, took place (study baseline measurements) as described in Textbox 1.

Phase III involved the development of clinical simulation scenarios (Cases 1-2) and measurement of variables. Roles were randomly assigned in a controlled environment, preserving both the intimacy as well as the confidentiality of the data, and all variables were measured immediately before (pre) and after (post) Cases 1 and 2. The students subsequently underwent the corresponding defusing and debriefing sessions. One week later, the students participated in a second case (Case 2) involving the same patient, undergoing the same measurements. Subsequently, a further debriefing session took place.

Data Analysis

Data analysis was performed using the SPSS v.20.0 statistical software. Within the descriptive analysis of data, the categorical variables are expressed as the percentage, whereas the continuous variables are displayed as the mean and standard deviation. The Kolmogorov-Smirnov test was performed to evaluate the normality in the distribution of variables. When normality was verified, the Student's t-test for related samples was applied to both groups. Statistical significance was set at $P<.05$. Reliability and validity were ensured by using established tools and approved equipment for testing purposes, as reported above.

Results

Descriptive Data

The final sample comprised of 107 students included 95 (88.8%) women and 12 (11.2%) men. Regarding the age of the participants, 97 were below 25 years of age (90.7%) whereas 10 (9.3%) were older than 25. Regarding the students' professional experience in health care environments, 44 (41.2%) participants were experienced, whereas 63 (58.8%) had no experience. To facilitate the interpretation of the remaining results, these are presented below, for each of the comparisons performed, according to participants' experience.

Physiological and Psychological Variations Compared to Baseline Data

The normality of all variables was confirmed using the Kolmogorov-Smirnov test. Therefore, the Student's t-test for related samples was applied to each group between the baseline moment and before Case 1 (pre-Case1). In Group 1 (without experience) a significant increase was observed in subjects before Case 1 compared to their baseline parameters of systolic blood pressure (SBP) with $P<.001$, diastolic blood pressure

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(DBP) with *P*=.001, HR (*P*<.001) and stress (*P*=.004), as shown in Table 1.

In Group 2 (with experience) a significant increase was observed in subjects prior to Case 1 compared to their baseline parameters for SBP (*P*<.001), DBP (*P*<.001), HR (*P*<.001), and without this change being observed in the stress levels (*P*=.10), as shown in Table 1.

Physiological and Psychological Variations Between Pre- and Postparticipation in Simulation Scenarios

After confirming the normality of all the variables via the Kolmogorov-Smirnov test, the Student's t-test for related samples was applied to each group to determine whether significant differences existed between different moments in time: (1) before Case 1 and after Case 1 (pre-Case 1/post-Case 1), (2) before Case 2 and after Case 2 (pre-Case 2/post-Case 2), and (3) before Case 1 and before Case 2 (pre-Case 1/pre-Case 2). Regarding Group 1 (without experience) the physiological parameters (Table 2), the SBP did not display significant changes during Case 1. However, a significant decrease occurred between the SBP before Case 1 and 2 (*P*=.01), as well as a significant increase during Case 2 (*P*=.001).

Regarding DBP, a significant decrease was observed (*P*=.02) between Cases 1 and 2, whereas within each of these cases there was no significant result (Table 2). In the case of HR, as with the SBP, a significant increase occurred during Case 2 (*P*<.001) as well as a significant decrease between Cases 1 and 2 (*P*=.01). Regarding Case 1, significant results did not occur between the moments in time (before and after), as shown in Table 2. In the case of the psychological parameters, a significant decrease in stress occurred before and after Case 1 (*P*=.003), as well as before Case 2, compared to Case 1 (*P*=.001). Regarding Case 2, we did not find significant changes between the different moments in time (before and after), as shown in Table 3.

Concerning state anxiety (Table 3), the subjects presented a significant decrease in Case 1 (*P*=.006), and during Case 2 (*P*=.002). However, significant differences were not found between Cases 1 and 2.

In Group 2 (with experience), regarding physiological parameters (Table 2), the SBP did not present significant changes in any of the cases under study. In the case of DBP, a significant decrease was found (*P*=.03) in Case 1 and between Cases 1 and 2 (*P*=.001). Regarding Case 2, significant results were not found between the different moments in time (before and after), as displayed in Table 2. Regarding HR values, subjects presented a significant increase of the same in Case 2. However, a significant decrease was not found between Cases 1 and 2 (*P*=.002). In Case 1, significant results did not occur when comparing the before and after values, as observed in Table 2. Concerning psychological parameters**,** only in Case 1 there was a significant decrease in stress (*P*=.002). There was no other significant effect in relation to this variable (Table 3). In the case of state anxiety (Table 3), participants presented a significant decrease in the same during Case 1 (*P*<.001). However, this was not significant in the remaining comparisons performed for this variable.

Table 1. The results of physiological resting variables and psychological variables measured at baseline and pre-Case 1, in both groups.

Variables	Baseline, mean (SD)	Pre-Case 1, mean (SD)	*P* value[a]
Group 1 (without experience)			
SBP[b] (mm Hg)	112.1 (7.8)	120.9 (12.0)	<.001
DBP[c] (mm Hg)	66.2 (6.2)	70.0 (9.0)	.001
HR[d] (bpm)	72.7 (11.7)	83.4 (19.4)	<.001
Stress	5.4 (2.6)	6.2 (2.0)	.004
Group 2 (with experience)			
SBP (mm Hg)	113.9 (9.00)	121.9 (10.2)	<.001
DBP (mm Hg)	68.6 (6.0)	75.4 (8.0)	<.001
HR (bpm)	77.0 (13.6)	86.1 (13.9)	<.001
Stress	4.7 (2.8)	5.4 (2.4)	.10

[a]Statistical significance was set at *P*<.05.

[b]SBP: systolic blood pressure.

[c]DBP: diastolic blood pressure.

[d]HR: heart rate.

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Table 2. Results of the physiological variables measured for both groups during the different study moments.

Variable	Mean (SD)	*P* value[a]
Group 1 (without experience)		
Systolic blood pressure (mm Hg)		
Pre-Case 1	120.9 (12.0)	N/A[b]
Post-Case 1	120.5 (13.4)	N/A
Variation during Case 1	–0.3 (12.1)	.83
Pre-Case 2	117.7 (10.7)	N/A
Post-Case 2	121.8 (11.2)	N/A
Variation during Case 2	4.1 (9.5)	.001
Pre-Case 1	120.9 (12.0)	N/A
Pre-Case 2	117.7 (10.7)	N/A
Variation between both cases	–3.2 (9.7)	.01
Diastolic blood pressure (mm Hg)		
Pre-Case 1	70.0 (9.0)	N/A
Post-Case 1	70.3 (10.0)	N/A
Variation during Case 1	0.4 (7.1)	.70
Pre-Case 2	67.9 (9.2)	N/A
Post-Case 2	68.7 (7.1)	N/A
Variation during Case 2	0.8 (6.5)	.32
Pre-Case 1	70.0 (9.0)	N/A
Pre-Case 2	67.9 (9.1)	N/A
Variation between both cases	–2.1 (7.1)	.02
Heart rate (bpm)		
Pre-Case 1	83.4 (19.4)	N/A
Post-Case 1	84.8 (17.5)	N/A
Variation during Case 1	1.3 (11.6)	.38
Pre-Case 2	77.9 (12.7)	N/A
Post-Case 2	84.8 (14.0)	N/A
Variation during Case 2	6.9 (9.2)	<.001
Pre-Case 1	83.4 (19.4)	N/A
Pre-Case 2	77.9 (12.7)	N/A
Group 2 (with experience)		
Systolic blood pressure (mm Hg)		
Pre-Case 1	121.9 (10.2)	N/A
Post-Case 1	122.0 (15.0)	N/A
Variation during Case 1	0.1 (12.3)	.97
Pre-Case 2	119.7 (12.7)	N/A
Post-Case 2	121.0 (12.3)	N/A
Variation during Case 2	1.3 (11.5)	.47
Pre-Case 1	121.9 (10.2)	N/A
Pre-Case 2	119.7 (12.7)	N/A
Variation between both cases	–2.2 (9.7)	.15

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Variable	Mean (SD)	*P* value[a]
Diastolic blood pressure (mm Hg)		
Pre-Case 1	75.4 (8.0)	N/A
Post-Case 1	73.1 (9.8)	N/A
Variation during Case 1	–2.3 (6.8)	.03
Pre-Case 2	71.7 (8.8)	N/A
Post-Case 2	72.3 (7.8)	N/A
Variation during Case 2	0.7 (7.5)	.57
Pre-Case 1	75.4 (8.0)	N/A
Pre-Case 2	71.7 (8.8)	N/A
Variation between both cases	–3.8 (6.7)	.001
Heart rate (bpm)		
Pre-Case 1	86.1 (13.9)	N/A
Post-Case 1	84.9 (14.4)	N/A
Variation during Case 1	–1.2 (7.5)	.29
Pre-Case 2	80.3 (15.2)	N/A
Post-Case 2	84.5 (16.3)	N/A
Variation during Case 2	4.2 (8.3)	.002
Pre-Case 1	86.1 (13.9)	N/A
Pre-Case 2	80.3 (15.2)	N/A

[a]Statistical significance was set at *P*<.05.

[b]N/A: not applicable.

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Table 3. Stress levels, measured using the visual analogue scale and values of state anxiety measured using the State-Trait Anxiety Inventory (STAI)-E scale for both groups, during the different study moments.

Variable	Mean (SD)	*P* value[a]
Group 1 (without experience)		
Stress		
Pre-Case 1	6.2 (2.0)	N/A[b]
Post-Case 1	5.1 (2.7)	N/A
Variation during Case 1	–1.1 (2.8)	.003
Pre-Case 2	5.6 (2.3)	N/A
Post-Case 2	5.1 (2.6)	N/A
Variation during Case 2	–0.5 (2.7)	.17
Pre-Case 1	6.2 (2.0)	N/A
Pre-Case 2	5.6 (2.3)	N/A
Variation between both cases	–0.7 (2.0)	.01
State Anxiety		
Pre-Case 1	25.4 (10.0)	N/A
Post-Case 1	20.9 (11.7)	N/A
Variation during Case 1	–3.9 (11.8)	.006
Pre-Case 2	23.5 (11.6)	N/A
Post-Case 2	18.6 (11.7)	N/A
Variation during Case 2	–4.4 (11.0)	.002
Pre-Case 1	25.4 (10.0)	N/A
Pre-Case 2	23.5 (11.6)	N/A
Variation between both cases	–1.9 (10.0)	.26
Group 2 (with experience)		
Stress		
Pre-Case 1	5.4 (2.4)	N/A
Post-Case 1	4.4 (2.5)	N/A
Variation during Case 1	–1.0 (2.0)	.002
Pre-Case 2	4.9 (2.6)	N/A
Post-Case 2	4.5 (2.7)	N/A
Variation during Case 2	–0.4 (1.7)	.18
Pre-Case 1	5.4 (2.4)	N/A
Pre-Case 2	4.9 (2.6)	N/A
Variation between both cases	0.5 (2.0)	.09
State Anxiety		
Pre-Case 1	23.7 (9.1)	N/A
Post-Case 1	17.6 (10.2)	N/A
Variation during Case 1	–6.1 (9.4)	<.001
Pre-Case 2	20.8 (11.2)	N/A
Post-Case 2	19.4 (12.6)	N/A
Variation during Case 2	–1.4 (8.0)	.28
Pre-Case 1	23.7 (9.1)	N/A
Pre-Case 2	20.8 (11.2)	N/A

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Variable	Mean (SD)	*P* value[a]
Variation between both cases	–2.9 (8.7)	.10

[a]Statistical significance was set at $P<.05$.

[b]N/A: not applicable.

Discussion

Principal Findings

Different studies performed with both animals and humans have demonstrated the influence of hormones from the adrenal cortex upon the levels of stress, anxiety and physiological changes, and their relationship with learning. This demonstrates the influence of these hormones on memory and the individual perception of stress, together with its variations, before and after, any stressful situations [26-28]. On the other hand, as previously commented, high-fidelity simulation has a very high approximation accuracy to reality, by introducing the nursing student to realistic situations and contexts, similar to those that occur while providing care and which generate a high level of responses, both physiological as well as psychological and pedagogical. The results of our research indicate that the students who participated in the clinical simulation scenario began with values of BP, HR [29], general academic self-efficacy [30] and trait anxiety [20] which were within normal expected parameters in these age ranges.

Physiological Values

In students without experience**,** a statistically significant increase of SBP, DBP, and HR was observed immediately before students participated in the first case (Case 1) compared with their baseline levels. This coincides with the work by Muller et al [31]. This increase seems to be related to factors such as uncertainty, the development of the case, the type of role, the management of the material, and the anticipatory anxiety. Nonetheless, these values tend to return to baseline values after debriefing and participation in a new clinical simulation scenario in line with research conducted to date by Dyer and Byrne [32] and Megel et al [33].

After participation in the second case (Case 2-students without experience), there was a significant decrease in all the physiological parameters measured before facing the second case, which is indicative of lesser stress and a greater level of adaptation, similar to the data collected by Bong et al [34]. This finding may be related to the perception of self-efficacy students have once they have been able to practice their skills during the first case and after a debriefing, during which they receive feedback on their skills within the simulation context. As noted by Bandura [35], the biological system is activated according to the belief that one has of his or her own ability to perform a task. Nonetheless, an increase in the vital signs was observed in students without experience, these changes were significant for the SBP and HR, coinciding with subjects with experience. This data, considering that it is the second experience, may demonstrate a more significant implication or physical effort in the case as these changes are not accompanied by an increase in the levels of stress (Table 3), as manifested by the students at the end of the exercise via an open survey designed for gathering students' opinions regarding the simulation experience.

In the case of students with experience, the tendency of the vital signs is the same for students without experience. Initially, there is a significant increase in their baseline vital signs, which is probably related to the same causes mentioned in the group without experience. It is interesting to note that this group began with lower baseline levels, especially regarding stress and anxiety (Tables 1 and 3). Perhaps this variation is due to past professional experiences, which enable these students to view the context in a more familiar and less threatening way, thus providing them with a greater ability to adapt, as reflected in work by Karabacak et al [36]. This may be because they have acquired competencies due to vicarious learning, additional verbal information, and observation in their work context, as well as the perception of self-efficacy based on experience in a real health context.

When the students with experience participated in the second case (Case 2), an increase in HR was found (as occurred the group without experience). This was possibly related to the additional implication and effort and not due to an increase in stress, as previously noted. Furthermore, a decrease in all values was observed, which was statistically significant in the case of the DBP and the HR values, which also occurred in the group without experience, in accordance with the work by Dworkin et al [37], McKay et al [38] and DeMaria et al [39]. According to these studies, HR is a stable and reliable marker of the neuroendocrine response in situations of stress and is used with a greater frequency than the measurement of BP, as the latter is modified by many factors including instrumental complications for measurement of the same during a clinical simulation scenario.

Ultimately, an increase in the vital physiological signs was observed in both groups prior to participation in a first clinical simulation scenario, to later decrease, to a variable extent, according to experience and by serial participation in clinical simulation scenarios, which is in line with previous studies by Dyers and Byrne [32], Muller et al [31] and Bong et al [34].

Psychological Values

In both groups and measurements, both pre-Case 1 compared to its baseline, and measurements taken post-Case 1, post-Case 2, and pre-Case 1- pre-Case 2, a decrease in the levels of stress and anxiety was observed, which is a finding that is also described by Henrich et al [40]. A more detailed analysis of our findings shows that among students without experience, the stress levels, before Case 1, were significantly higher than at baseline. Indeed, these were even higher than in students with experience. This is a finding that, as described by McGuire and Lorenz [41], may be related to the emotional state when facing an unknown situation with a certain level of uncertainty and

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insecurity. This is reflected in the activation of the sympathetic system which, in this case, seems to tend towards an adaptive-constructive process, as these stress levels decrease after the first case, this being a significant decrease. After participation in the second case, the level of stress decreased. However, this is not statistically significant, probably related to the fact that, in this case (Case 2), the students displayed lower levels of stress thanks to their participation in the first case and having debated the same.

Concerning state anxiety, a significant decrease was also found. We can postulate that the measurement of stress is related to a specific act (a real threat) and that, once this has ceased, the levels of stress decrease much faster. This is in contrast with state anxiety which depends on many personal factors, such as the effective situation at that time, the perception of a safe environment in contrast to the real context or findings of making a mistake while being observed as described by Khadivzadeh and Erfanian [42]. Similarly, the levels of stress and anxiety compared pre-Case 1 and pre-Case 2 decreased. This may suggest, as previously mentioned, a process of familiarization with the simulator and teamwork, in line with findings by Allan et al [43]. Among students with experience and at all assessments, a decrease in stress and anxiety was found which, in some cases, was statistically significant, as this group began with lower baseline values of stress and anxiety. Nonetheless, and despite the uncertainty, the feeling of being observed or the management of equipment, the fact these students had some prior related experience could favor their reduced anxiety in a simulation context compared to reality, which coincides with recent findings [13].

Future Research Lines

From the teaching point of view, it would be interesting to devise proper practice guidelines to give students tools for being able to face clinical high-fidelity simulation experiences, in which a greater familiarization of students without experience is included, as well as ensuring students are gradually introduced to these methods. We believe it would be useful to perform studies on serial participation in clinical simulation scenarios to verify whether the levels of anxiety or stress show progression. Also, it would be useful to research whether markers of sympathetic activation, such as cortisol in saliva, alpha-amylase or perspiration can be determined to confirm the positive or negative influence of participation in clinical simulation scenarios.

Limitations

It is essential to consider the sample size, although, to our knowledge, according to our literature search, this study has the highest number of subjects to date. On the other hand, we cannot affirm that the differences obtained between groups are only due to experience, as age may have a substantial influence upon vital signs, as well as aspects regarding the students' personality, self-esteem, or fear of evaluation by peers. Therefore, a more significant sample is needed in future studies to perform a multivariate analysis. Also, the consecutive sampling method may be another limitation which should be considered in future studies.

Conclusion

Participation in clinical simulation scenarios influences students both on a physiological and psychological level. In all students under study, vital signs increased before participation in a clinical simulation scenario, especially the heart rate. Furthermore, an increase in stress levels was observed, as well as in anxiety before their first simulation case. Both study groups (students with and without experience), demonstrated a decrease in the vital signs and levels of stress/anxiety, possibly related to the effects of participating in the case study scenarios as well as the debriefing sessions and subsequent simulation sessions, which suggests a positive adaptive process. Possibly, the incorporation of a simulation designed with different levels of complexity and realism, throughout the courses, helps to normalize vital signs and stress levels to figures close to normality before participation of students in these teaching methods.

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Abbreviations

BP: blood pressure
CPR: cardiopulmonary resuscitation.
DBP: diastolic blood pressure
ERC: European Resuscitation Council
HADS: Hospital Anxiety and Depression Scale
HFCS: high-fidelity clinical simulation
HR: heart rate
SBP: systolic blood pressure

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