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Evaluating Compliance, Acceptance, and Intensity of a Custom Virtual Reality Exergame for Hospitalized Children with Cancer: A Pilot Study

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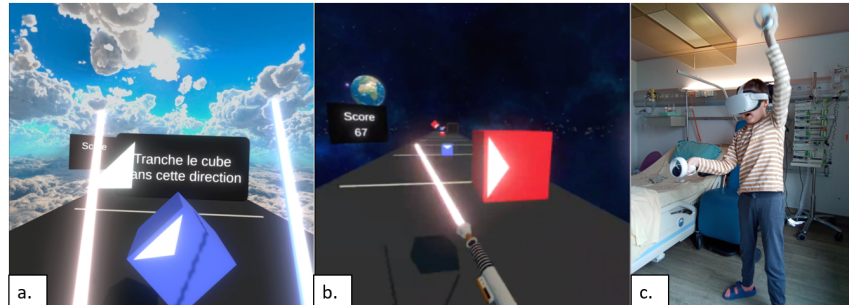


Figure 1: a. Start gamescreen in sky environment; b. Game session with obstacles; c. Child playing the VR-based exergame

ABSTRACT

Exercise improves health outcomes in hospitalized children with cancer but is often limited by various barriers. Virtual Reality (VR)-based exergames offer a promising solution. This study evaluated the acceptance, compliance, and intensity of a custom VR-based exergame program for pediatric cancer patients in a hospital setting. Thirteen children participated, achieving a compliance rate of 68% and an average intensity of 4.92 Metabolic of tasks (MET), meeting recommended moderate-to-vigorous physical activity (PA) levels. The findings suggest that this VR-based exergame is a promising and engaging intervention to promote exercise in children with cancer during treatment, with minimal risk of cybersickness.

Index Terms: Human-centered computing — Human computer interaction (HCI) — Interaction paradigms — Virtual reality, Applied computing — Life and medical sciences — Consumer health.

1 PROBLEM STATEMENT AND OBJECTIVES

Cancer remains one of the leading causes of mortality worldwide, accounting for 10 million deaths in 2020. The pediatric population is not exempt, with approximately 2,260 children diagnosed with cancer annually in France [3]. Treatment typically involves inten-

sive interventions such as chemotherapy, immunotherapy, surgery, radiotherapy, and hematopoietic stem cell transplantation. These treatments, combined with the disease itself, impose significant physiological (e.g., reduced strength and aerobic capacity) and psychological (e.g., stress, anxiety, isolation) burdens, with fatigue being the most reported symptom [2]. As a result, the quality of life (QoL) of pediatric cancer patients is often severely impacted.

Over the past decade, exercise has emerged as a widely recognized non-pharmacological strategy to alleviate these side effects. In this context, it refers to exercise tailored to an individual's physical and mental capabilities. Numerous benefits have been documented, including enhanced QoL, emotional well-being, self-esteem, reduced cancer-related fatigue, and improved physical fitness [2]. According to the World Health Organization (WHO), children and adolescents should engage in an average of 60 minutes per day of moderate-to-vigorous physical activity (> 3 MET), primarily aerobic, to promote cardiorespiratory fitness, bone health, and mental well-being. However, pediatric cancer patients consistently exhibit lower levels of physical activity compared to their healthy peers. Various barriers hinder their participation in exercise, including fatigue, psychological challenges (e.g., anxiety, low motivation), and cancer-specific limitations. For example, leukemia patients often face prolonged hospitalizations and isolation in sterile environments, while those with solid tumors may encounter movement restrictions due to amputation or tumor location [1].

Emerging digital solutions provide novel opportunities to address these barriers. Among these, exergames—interactive video games that combine exercise with gameplay—have gained popularity as an engaging and accessible means to promote exercise. Evidence suggests that exergames can enhance endurance, improve QoL, and reduce cancer-related fatigue for patients with cancer [6]. Among this population, exergame interventions demonstrate high acceptability, with participation rates exceeding 50% and no serious adverse events reported [6]. Within this domain, VR using Head-Mounted Displays (Fig. 1.c) stands out as a particularly promising platform to enhance the positive effects of exergames. By immers-

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ing children in a 3D environment with six degrees of freedom, VR increases engagement and motivation, offering a stronger sense of escapism compared to traditional exergames [4]. Although VR-based exergames have shown promise in promoting physical activity, their use in pediatric oncology remains unexplored. This study aims to assess the compliance, acceptance, and exercise intensity of pediatric cancer patients undergoing treatment with a VR-based exergaming program, exploring its application in a hospital setting.

2 METHODOLOGY

VR-based exergame sessions of 30-minutes maximum were offered 4 afternoons per week to children hospitalized in a pediatric oncology unit and aged between 6 and 17 years old. Adapting how children interact with the virtual environment to their specific needs and abilities is critical. Thus, the VR-based exergame tested was a game developed by the lab team, in which players use virtual sabers to slice blocks (Fig. 1). Each game lasts five minutes and includes customizable options, such as playing while sitting or standing, using one or both arms, or adding obstacles (Fig. 1.b). The VR HMD used was a Meta Quest 2. The study focuses on three key measures:

- **Compliance** was measured by the percentage of sessions completed to those offered by each participant.
- **Acceptance** was assessed using a tablet-based questionnaire based on the Technology Acceptance Model [7]. Six components were scored from 0 to 6. Among them, user experience refers to both hedonic and pragmatic qualities, while nausea and oculomotor symptoms (mean of 10 items) are referred to as a cybersickness score experienced during practice.
- **Exercise Intensity** was estimated by heart rate monitoring, with energy expenditure estimated in MET, an indicator of exercise intensity per an adapted model by Lee et al. [5]. Exercise intensity must be in line with WHO recommendations.

3 RESULTS

Tab. 1 reports the mean and standard deviation of the variables of interest by cancer type. Of the 14 eligible children, 13 agreed to participate in the study (7 with Leukemia, 6 with Sarcoma), resulting in a participation rate of 92.9%. A total of 131 rounds of this exergame were played. The mean compliance rate was 68%, consistent with the rates observed in previous studies on exergames [6]. For both cancer types, participants reported high acceptance of the VR-based exergame, with strong scores in user experience. Importantly, no major cybersickness effects were observed. Regarding exercise intensity, VR-based exergame achieved moderate levels, with an average of 4.92 ± 2.09 MET, which met WHO recommendations for physical activity.

Table 1: Main results by cancer type.

Characteristic	Overall	Leukemia	Sarcoma
Compliance (%)	68 ± 28	66 ± 27	70 ± 34
User Experience	5.36 ± 0.51	5.72 ± 0.48	5.00 ± 0.17
Cybersickness	0.37 ± 0.23	0.20 ± 0.17	0.53 ± 0.12
Intensity (METs)	4.92 ± 2.09	5.34 ± 2.37	4.44 ± 1.43

4 DISCUSSION / PERSPECTIVES

This initial two-month experiment suggest that the use of VR-based exergame represents a promising complementary strategy to traditional supportive care for hospitalized children with cancer for both main pediatric cancer types. In fact, children showed marked interest in this type of program, with compliance rates suggesting strong adherence, especially among younger participants. In line, acceptance scores were very high. No cybersickness occurred during the experimentations, a crucial consideration given the potential vulnerability of this population. In line with WHO recommendations,

a moderate intensity was reached during exergame sessions. Thus, regular use of this VR-based exergame could potentially bring similar benefits to those of traditional exercise. This VR-based exergame does not replace the exercise supervisor, who remains essential for guiding the activity. However, using the VR-based exergame does not add to the supervisor's workload, is low-cost, and is well-suited for use in a hospital setting. The validity of the Lee model for estimating exercise intensity has not been assessed in children with cancer. Then, there is a need to develop an exercise intensity estimation methodology better suited to pediatric needs and hospital constraints. Regarding methodological constraints, the small sample size, inherent to the specific population studied, represents a limitation. The limited data availability restricts generalizations, and a larger-scale study would be needed to validate these findings. Future experiments should explore the potential for inclusion of additional pediatric oncology departments. Now, future experiments should better characterize the exercise provided by the VR-based exergame in terms of physiological, kinematic, and emotional responses. This detailed characterization will inform the development of an adaptive system capable of real-time adjustments to the exergame based on multiple data inputs. This would potentially enhance health benefits and compliance, aligning specific objectives for each patients by adapting the game through individual motivations. Moreover, a larger-scale data implementation could be considered. Adding more content and diversifying the data collected could promote a more intense and tailored exercise experience. In this regard, project proposals are underway to develop a comprehensive platform that combines VR-based exergames with extensive data collection in order to better understand the impact of exercise in pediatric oncology.

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