Supporting Physical and Mental Health Rehabilitation at Home with Virtual Reality Headsets and Force Feedback Gloves

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ABSTRACT

The outbreak of COVID-19 has led to worldwide quarantines and telehealth has become the lifeline for patients prone to infection. We propose using a Virtual Reality (VR) system as a playful coping strategy for rehabilitation at home. We hypothesize such a system can improve the physical and mental well-being of the user during play. In this demonstration, we transform the therapy into a playful virtual cat bathing simulation using a VR headset coupled with force feedback gloves. This results in an engaging and feedback-rich scenario where users practice fine motor skills by progressively completing three cat-care tasks.

Index Terms: rehabilitation, virtual reality, force feedback

1 INTRODUCTION

There is a wide consensus that the COVID-19 pandemic and related containment measures, such as quarantine, social distancing, and self-isolation, can have a detrimental impact on well-being. Even though hospitals and clinics around the world are modifying their practices in order to support people who are suffering in the pandemic, the number of people unable to access immediate facilitation still increases as the situation escalates. VR has promise for rehabilitation due to its capability of providing immersive, often entertaining, approaches to accomplishing improvements in performance [4]. VR-facilitated therapies can be delivered within a functional, purposeful and motivating context, rehabilitating cognitive and functional abilities, and provide interactive scenarios designed to target client needs through exposure to simulated "real-world" or analogue tasks [5].

We aim to investigate the emergent use of VR and force feedback gloves to create a rehabilitation experience, which we hypothesize can improve the physical and mental well-being of the user during play. The rehabilitation is conveyed through a virtual cat bathing task, creating an abundant, engaging, and feedback-rich scenario for users. We conjecture the game can help users to progressively conduct domestic rehabilitation, manage stress, and stay active when they are trapped at home alone. The coupling with haptic feedback, enabled by force feedback gloves, allow the immersiveness of the virtual experience, or the "sense of presence", to be enhanced. The system thus potentially provides a coping strategy for vulnerable people in need of physical and mental rehabilitation but prone to infection in this pandemic. Future research will use rigorous user studies to compare this VR approach against "real-world" rehabilitation in terms of its effectiveness and enjoyment and to fully tease out all positive and negative qualities induced with this style of therapy.

2 RESEARCH FOCUS

While the majority of VR rehabilitation systems provide a visual- and audio-based interaction process, the haptic aspect of the interaction in VR-enhanced rehabilitation has not attracted as much attention. Being identified as a significant signal for improving a user's performance in difficult tasks, haptic information is vital for the construction of a multidimensional and multisensory virtual environment, enhancing immersion and enabling a richer user experience. For example, Bortone et al. [1] combined VR and wearable haptic devices for rehabilitation of the upper limbs. However, in general, the integration of VR and haptic information in rehabilitation remains under-explored, despite numerous potential benefits in terms of immersion and enjoyment. To explore the efficacy of this promising combination in rehabilitation, we have developed a VR system that allows users to rehabilitate their fine motor skills, as well as mental health, through a cat bathing task. We hypothesize that participating in such a task may effectively help users practice their fine motor skills and also potentially mitigate depression, anxiety, stress, and loneliness through a playful experience, which is associated with providing motivation towards the accomplishment of a self-imposed goal and tendencies towards active involvement [3].

Figure 1: A participant is trying the system with an HTC Vive HMD and Dexmo gloves.

3 IMPLEMENTATION

We implemented a VR prototype called *VRCatBath* with all virtual scenes developed in Unity3D Game Engine using the relevant device SDKs. We used an HTC Vive head-mounted display (HMD) for the visual embodiment in VR. The motion capture and the force feedback in VR was provided by Dexmo gloves, which is a lightweight mechanical exoskeleton system [2]. In combination with the immersive environment created by the HMD, a realistic sensation of interaction is provided by the system when users carry out the cat bathing task.

4 TASK

To start the rehabilitation procedure, the user needs to wear the VR HMD and the gloves and stand or sit in a space without obstacles that may hurt him or her during the task. The bathing task consists of three subtasks, which correspond to the procedures required before, during and after bathing. Each subtask contains a few goals that need to be achieved by the user through certain steps, which leads to the unlocking of the next subtask. Successfully completion of all

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978-0-7381-1367-8/21/$31.00 ©2021 IEEE
DOI 10.1109/VRW52623.2021.00225

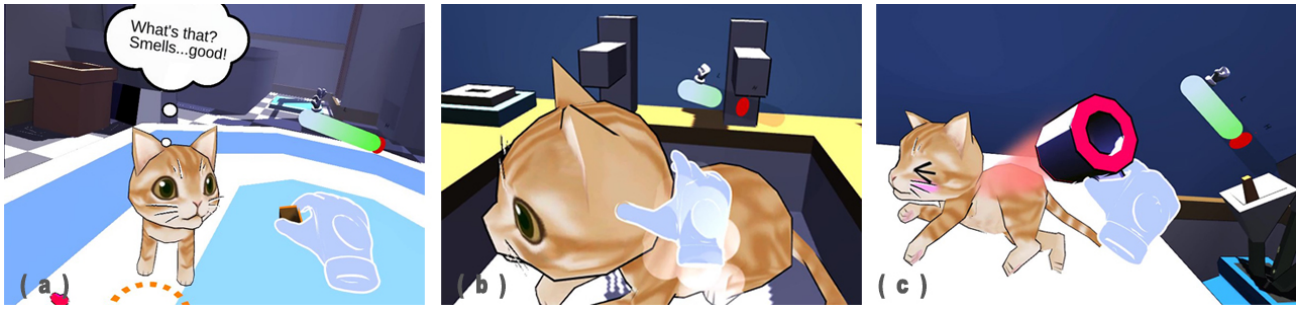

Figure 2: The bathing task comprises three subtasks: (a) food treating; (b) massaging; and (c) blow-drying.

three subtasks ensures adequate exercise for each user on a daily basis.

4.1 Task Goals

Task 1: food treating. The game starts by preparing the cat for the bath psychologically through food treats. The user pleases the cat with a plate of cube-shaped cat food by grabbing and placing the food in front of the cat. To move food of various sizes, the user needs to apply and maintain a moderate pinching force to avoid the food cubes crumbling.

Task 2: massaging. After the feeding, the second scene will be unlocked where the cat will be sitting in the basin, waiting to be cleaned and massaged. The user applies a grasping force on its body to massage the cat and produce bubbles. The cat has different levels of sensitivity and force tolerances over its body. Brutal forces will irritate the cat.

Task 3: blow-drying. In the final scene, the user blow-dries the cat with a hair dryer. The air force depends on the distance between the hair dryer and the cat and the power of the hair dryer, modulated by how hard the user squeezes the handle. However, excessive power in the hair dryer causes more noise and heat that in return makes the cat uncomfortable. Therefore, not only should the flow of hot air be correctly directed towards the cat by rotating the hand. A balance should also be sought between the distance of the cat and the hair dryer and the force exerted on the hair dryer's handle.

4.2 Cat States

The states of the cat are reflected through its movements, sounds, and monologues and these outputs serve to imply its requirements and provide feedback in response to the user's actions. This is a playful mechanism to let the the user know the actions needed at the current stage to achieve the goal. For example, a monologue, such as "*Put it in the circle, maybe I'll have a few bites.*" is a hint suggesting the user to feed the cat as a way to ease its nervousness before the bath. "*Ooh, that does feel nice.*" is positive feedback affirming the the user's actions; while "*Ouch, you are hurting me, you foolish human!*" is an example of negative feedback. The states of the cat serve as instructions for the users, helping them evaluate the effectiveness of their actions, as well as to drive the plot of the playful experience. Success is quantified as the *friendliness* of the cat, which captures the willingness of the cat to cooperate with the user in completing the bathing task. If this value decreases to zero before the user completes all tasks, the game is over and the user has to start from the beginning.

4.3 Measures

Through the interaction with the food and the hair dryer, as well as physical contact with the cat, such as petting and massaging, we hypothesize the physical and mental well-being of the user is improved during play. The game features motion control, mainly involves dexterity, eye-hand coordination, in-hand manipulation, grasping and prehensile patterns and bilateral coordination. The performance of the user is assessed from two aspects: action quality and completion time, and these measures are reflected in the *friendliness* attribute of the cat. While the value of *friendliness* decreases linearly over time, the user's performance can accelerate or decelerate the reduction in friendliness. The hardware system measures the user's actions and provides physical guidance by applying force feedback on the finger joints of the user using the mechanical exoskeleton glove. Optionally, the measures can be used to grade and document the therapeutic intervention to support further treatment planning.

5 Conclusions

The outbreak of COVID-19 has led to worldwide quarantines and telehealth has become a pragmatic option for patients prone to infection in this pandemic. We have presented *VRCatBath*—a playful VR system, which we hypothesize can improve the physical and mental well-being of the user during play. In this demonstration we have created an immersive therapeutic experience involving a virtual cat bathing task using a VR device coupled with force feedback gloves. This resulted in an engaging and feedback-rich scenario where users progressively interact with the virtual cat and necessary tools using fine-grained forces to complete the task. The process specifically practices fine motor skills, such as bilateral coordination and dexterous operations. The hardware used is either off-the-shelf (HMDs) or being prepared for mass manufacturing (Dexmo gloves). We therefore hope *VRCatBath* will be a prototype for future inexpensive playful VR therapy experiences after this unprecedented global health crisis.

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