Comparing Objective and Subjective Metrics Between Physical and Virtual Tasks

S.N. Gieser[1(✉)], Caleb Gentry[1], James LePage[2,3], and Fillia Makedon[1]

[1] Heracleia Human Centered Computing Laboratory, Department of Computer Science and Engineering, University of Texas at Arlington, Arlington, TX, USA
{shawn.gieser, makedon}@uta.edu, caleb.gentry@mavs.uta.edu
[2] Veteran Affairs North Texas Health Care System, Dallas, TX, USA
james.lepage@va.gov
[3] University of Texas Southwestern Medical Center, Dallas, TX, USA

Abstract. Virtual Reality (VR) is becoming a tool that is more often used in various types of activities, including rehabilitation. However, studies using VR rehabilitation mainly focus on comparing the performances of participants, but not their opinions. In this paper, we present a virtual version of the Box and Blocks Test. We also present the results of a pilot study where participants completed a physical version of the Box and Blocks Test and the virtual version, comparing their scores and opinions. We also compare how the participants viewed the passage of time while performing both versions as a way to see how engaged they were during the task.

Keywords: Box and blocks test · Leap motion · Upper extremity rehabilitation · Gamification · Virtual reality · Time perception

1 Introduction

The onset of low-cost, off-the-shelf sensing equipment, such as the Leap Motion [1], have made Virtual Reality (VR) more easily accessible to everyone. It has also expanded the use of VR and virtual environments into many different fields, such as driving simulations, cooking, vocational training, and rehabilitation [2–5]. When VR is used in rehabilitation, exercise programs can provide more interesting and engaging tasks, causing patients to perform better and recover quicker than traditional rehabilitation [6]. Research has shown that therapists would use certain types of VR technology in a home environment without their presence, creating a form of tele-rehabilitation [5].

However, with this advent of VR rehabilitation, would people want to perform a VR version of exercises and tasks, or would they rather do the traditional physical version Also, other questions can be asked too, such as which version do people find more fun, more frustrating, or which would they rather do again? This paper aims to answer these questions by presenting a virtual version of an Occupational Therapy assessment task called the Box and Blocks Test using the Leap Motion. This virtual version was then

S. Lackey and R. Shumaker (Eds.): VAMR 2016, LNCS 9740, pp. 3–13, 2016.
DOI: 10.1007/978-3-319-39907-2_1

compared to the tangible and traditional physical version by having participants perform both tasks and recording their performance. We will also compare how participants perceive the passage of time to see which version they were more engaged by. Lastly, we will compare their subjective opinions of the participants to see which version they prefer and why, as well as their overall opinions of the technology being developed.

2 Background

The Box and Blocks Test is an assessment used in Occupational Therapy used to evaluate gross manual dexterity [7]. This is done by having a participant sit in front of a box with a partition in the middle, and having them move blocks from one side to the other. The goal is to move as many blocks as the participant can in a one minute time period. Blocks can only be moved one at a time. The test is at first uses only the participant's dominant or non-affected (for people with disabilities) hand, moving blocks from the same side as the dominant hand to the other. The participant get a point for each block they move over. Carrying multiple blocks over at once only counts as one point. If the hand does not completely cross the partition (i.e. the block is thrown over), that block is not counted towards the score. If a block bounces out of the box and lands on the table or the floor, that block is still counted and the participant does not have to pick it up. After one minute has passed, the blocks are counted and the test is reset to be repeated with the person's non-dominant or affected hand.

The assessment of activity engagement can be done by simply asking participants to what degree they enjoyed the activity; however this can create expectation demand which bias the participants' self-reports. To avoid these demand characteristics, more indirect means of assessing engagement is required. A relatively simple way of indirectly assessing engagement is through the assessment of perceived time while performing a task.

Characterized by the idiom "time flies when you are having fun," research has shown that being exposed to engaging positive activities or stimuli results in individuals underestimate the amount of time that has passed, while individuals tend to overestimate time passing when under negative conditions [8–10]. In practical terms, being exposed to positive stimuli such as pictures of desserts or pleasurable tactile stimulation [11] result in an underestimation of exposure time. Factors such as pain [12] and fear [13] have been associated with an overestimations of the time passed.

3 Related Work

Using VR has been shown to have many strengths when applying it to rehabilitation, as it provides stimulus control, consistency, and real-time performance feedback. VR also allows the adaptation to a patient's abilities, and the ability to distract and motivate a patient [14]. In fact, VR can be used for patients of all ages, helping adults regain the ability to perform activities of daily living [15] to children with Cerebral Palsy to improve motor performance [16]. The Leap Motion has been evaluated for game based therapy. Clinicians and therapists have shown positive feedback when viewing the

Leap Motion's use for therapy [17], and that it has the potential to be used in a home environment with younger users [5].

The Box and Blocks Test has been used in many stages of studies that involves VR rehabilitation, such as evaluation of VR tasks or even being the task performed. The performance of people performing VR tasks and games created is correlated to the scores of that same person performing the Box and Blocks Test [15]. The scores from the Box and Blocks Test are also used as inclusion and exclusion from studies that involve VR games as well [18]. There have been versions of the Box and Blocks Test created in a virtual environment using both a Wii and a Kinect [19, 20]. However, these two studies only showed the performance between the different versions, and did not consider the opinions of the participants performing the task.

Not surprising, video and computer games have also demonstrated distortions in perceived time passing while engaged. For example, when time performing the activities were the same, the perceived time playing a video game was shorter than reading on a computer [21]. Additionally, in a comparison of expert and novice gamers, expert gamers perceived time as passing more quickly than novices after 30 and 60 min of play. While initially novice gamers perceived time as going slower while they were learning the game after 90 min they had similar time experiences as experts as their experience increased [22].

4 Experimental Setup and Procedure

For this experiment, we had participants perform two different versions of the Box and Blocks Test. The first version was a traditional version that could be touched. The second version was a virtual version done on a computer, lacking any tactile feedback. All participants participating in this pilot study were from a healthy general student population. The rest of this section will describe the two different versions followed by the experimental procedure.

4.1 Physical Version

The physical version used in the study was 3D printed. The goal with the physical version of the test was simply to recreate the size and shape of the original test. The box has a partition dividing it in half with all of the blocks on one side, where the subject was asked to move all blocks from one side of the partition to the other in one minute [7]. The goal was to see their ability to reach and grab the blocks, and quickly move them over the partition to drop them into the other side. The physical setup used for this experiment is shown below in Fig. 1 Left. The box and blocks were designed using SolidWorks CAD software, and printed using Makerbot Replicator 2 and Polyprinter 229 3D printers. The reason for this design was centered around some physical goals for the equipment.

Firstly, it was desired that the physical version be mobile, and easy transport to the different subjects in the test. Thus, it was decided that rather than making the box and blocks out of wood, which would be heavy, plastic puzzle pieces would be light,

Fig. 1. (Left) Physical version that was 3D printed. (Right) Virtual version that was created in Unity using the Leap Motion.

and easy to place into a box for easy transportation. Additionally, if any piece of the box broke, a repair would be easy, requiring only that the broken part be reprinted and then the experiment could easily continue. Thus, this design was more mobile and robust, allowing the experiment to be performed accurately on a continuous basis. In order to accomplish this, the parts needed to be designed using dovetails for a "puzzle-piece" fitting process. This allowed the parts to be easily printed, easy to assemble, and easy to transport.

4.2 Virtual Version

A virtual version of the Box and Blocks test was developed using the Unity Game Engine [23], which can be seen in Fig. 1 Right. All components were developed to be a scale model of the physical version in comparison to the size of a virtual hand. This allowed the virtual version to be an accurate recreation of the physical version and would require participants to perform the exact same actions to complete the Box and Blocks Test. This virtual environment was displayed on a computer monitor.

A Leap Motion was used to capture the motion of the hand. Grabbing the blocks in the virtual world is done in a similar fashion to that of the physical version. When a participant's fingers were near a block and then brought their fingers close together in a pinching fashion, a block was bound to the participant's thumb on their virtual hand. When they moved their fingers apart, the block would be released from the thumb and fall from the hand. This prevented multiple blocks to be picked up at once. The physics model for the hand was turned off to make it easier for the participant to move their virtual hand and pick up blocks without causing other blocks to fly around the environment. The score was automatically tracked and increased each time a block was placed in or fell into the other side of the box.

For gameplay, timers were implemented for the fifteen second practice and the sixty second full sessions that turn off sensor input upon completion. During the full session, the data from the Leap Motion is recorded so that it can be analyzed later and turned into a report for therapists. These data points include, but not limited to, the wrist position, palm position, fingertip positions, and joint angles.

4.3 Experimental Procedure

Twelve participants took part in this pilot study. After obtaining consent, the participants were given a survey asking the following questions:

- Demographic questions, such as age, gender, and ethnicity
- Have you had any experience playing video games? Significant/Some/No Experience
- Have you had any experience with virtual reality? Significant/Some/No Experience

Then, the concept of the Box and Blocks Test was described to the participants. Afterwards, the participants performed both the physical and virtual versions in one minute and five minute formats. The order of the tasks were complete were balanced in order to not show any bias towards a certain version. The order of tasks can been seen in Table 1.

Table 1. Order of tasks completed by participants

Participant number	Task 1	Task 2	Task 3	Task 4
1, 5, 9	Physical One-Minute	Virtual One-Minute	Physical Five-Minute	Virtual Five-Minute
2, 6, 10	Virtual One-Minute	Physical One-Minute	Physical Five-Minute	Virtual Five-Minute
3, 7, 11	Physical One-Minute	Virtual One-Minute	Virtual Five-Minute	Physical Five-Minute
4, 8, 12	Virtual One-Minute	Physical One-Minute	Virtual Five-Minute	Physical Five-Minute

Both the one minute physical and virtual versions were similar to the original procedure [24], with the physical being exact, and the virtual having minor modifications. The one minute tasks consisted of an optional practice period followed by the actual test. The practice period for the physical version followed the standard rules of fifteen seconds. The virtual version's practice period did not have a time limit, but lasted until the participants had a firm understanding of how to pick up blocks in the virtual world. After the practice period, the participants than performed the Box and Blocks Test with both hands with both versions. The participants' score was recorded after each one-minute tasks.

After the one-minute tasks, the participants were given another survey to see what their opinions were of the two different versions. The questions can be seen in Table 5 in Sect. 5, along with the results of the survey.

Once the survey was completed, the participants were then asked to do a five minute version of both the virtual and the physical tasks. If they ran out of blocks on one side of the box, the participants started moving blocks back to the other side without changing hands. The participants were not told when five minutes were over, but were told to stop whenever they felt five minutes have passed. All other rules of the one minute version still applied to the five minute version. The five minute tasks were performed with both hands. The scores and the elapsed time since the start of the task till the participants stopped were recorded.

A short video explaining the procedure and technology used can be seen here: https://youtu.be/ej5ZQBTGDWU .

5 Analysis and Discussion

Below, in Table 2 is the demographic information of the student population that participated in this study. The rest of this section will detail the rest of the results obtained.

Table 2. Demographic information of student participants

Population characteristics	Number of participants	Percentage
Male	9	75 %
Age		
18– 24	6	50 %
25– 34	4	33 %
35– 44	2	17 %
Ethnic or racial minority	3	25 %
Bacherlors Degree or Higher	6	50 %
Right Handed	10	83 %

5.1 Experience with Video Games and VR

Experience with video games and virtual reality was assessed on a three point self-report measure: No Experience, Some Experience, and Significant Experience. Though this was a very crude evaluation tool, it does allow students to easily classify their experience.

As shown in Table 3, there was a fair amount of variability in the response of the students with only one student reporting "Significant Experience" with virtual reality.

To improve the interpretability of the results, scores were coded: No Experience = 0, Some Experience = 1, and Significant Experience = 2. The two scales were summed. Students were then split into two groups, Low Experience (scores of 0 or 1, N = 5) and High Experience (scores greater than 1, N = 7).

Table 3. Participants experience with video games and virtual reality

Level of experience	Number of participants	Percentage
Video Game Experience		
No Experience	3	25 %
Some Experience	3	25 %
Significant Experience	6	50 %
Virtual Reality Experience		
No Experience	5	42 %
Some Experience	6	50 %
Significant Experience	1	8 %

5.2 Comparison of Scores on Physical and VR Tasks

As expected, students scored higher,, in the physical task compared to the virtual task, as seen in Table 4. At the one minute mark using the dominant hand, students physically moved 53.6 (sd = 7.1) blocks compare to 19.3 (sd = 5.0) moved through the computer interface. The results on the non-dominant had were very similar with 55.7 (sd = 6.7) moved in the physical task and 19.5 (s.d = 5.1) moved in the computer task. Paired comparisons between modalities were significantly different ($p < .001$).

Table 4. Number of blocks moved by each participant

Participant number	Physical		Virtual	
	Right	Left	Right	Left
1	44	48	26	21
2	55	57	24	25
3	58	50	27	28
4	49	46	21	17
5	62	61	16	24
6	56	69	20	21
7	58	52	12	12
8	60	55	13	14
9	63	60	20	13
10	45	46	20	18
11	45	51	21	15
12	59	62	15	24

Overall the it appeared that experience with video games and VR was associated superior ability to perform the computer task as the level of video game/VR experience was positively correlated with total blocks moved in the computer task, $r = .834$, but not in the physical task, $r = .101$. Contrary to expectations, the association between the total moved with both hands was insignificant $p > .5$.

5.3 Time Perception

Students, when asked to stop when they perceived five minutes had passed, spent approximately the same amount of time on the each modality. Total time spent of both dominant and non-dominant hands were 545 s (sd = 204) for the physical task and 536 (sd = 227) for the computer task, $p > .5$.

When the analysis was done between Low and High Experience students, there was a significant difference in the time spent performing the computer task. Those with High Experience performed the task for 427 s (sd = 169) compared to the Low Experience students who performed the task for 689 s (sd = 223), 2 min more.

5.4 Student's Subjective Experience

The subjective experiences of the students were evaluated. Table 5 presents the questions asked and the preferences of the students. As can be seen, the physical task was viewed as easier and less frustrating by the majority of students. Of note, the majority of students felt that technologies like the one used here should be developed to improve rehabilitation and would recommend this type of system to a family member.

Table 5. Subjective comparison of physical and virtual based tasks

	Physical		Computer		No preference	
	n	%	n	%	n	%
Which version was more fun?	6	50 %	4	33 %	2	17 %
Which version was more frustrating?	0	0 %	10	83 %	2	16 %
Which version was more stressful?	3	25 %	6	50 %	3	25 %
Which version make you more tired or worn out?	5	42 %	5	42 %	2	17 %
Which version required more work?	2	17 %	9	75 %	1	8 %
Which version would you rather do again?	7	58 %	3	25 %	2	17 %
Ratings on 1–10 with 10 being the highest					Average	SD
How useful do you think the tehcnology would be in assisting in rehabilitation?					7.1	2.1
If you were asked to use this type of technology for rehabilitation at home, how likely would you use it?					7.2	2.1
How strongly do you feel these types of technologies should be developed?					9.4	0.9
Would you recommend a friend or family member to use this technolgoy in their rehabilitation?					N	%
Yes					9	75 %
No					0	0 %
No Opinion					3	25 %

One interesting finding was that the subjective ratings appear, in part, related to the amount of experience the student had in video games/VR. In the item "Which version was more fun?" zero (0 %) of students in with Low Experience felt the virtual task was more 'fun'; this is significantly lower than the High Experience students where four (57 %) reported the virtual task was more fun, $X2(2, N = 7) = 8.6$; $p = .004$).

There were two common comments that were received by the participants about why the virtual version was harder and more frustrating. The first was that it was very difficult to grab the blocks at times in the virtual version. The second was that it was sometimes hard to perceive where the fingers were and what block you would be picking up.

6 Conclusions

In this paper, we have presented a virtual version of the Box and Blocks Test. We compared the scores and opinions of student volunteers who performed both the physical and virtual versions of the test. We showed that the amount of experience with video games and VR was positively correlated with their performance of the virtual task. We also compared their time perception during the two different tasks, showing that students with less video game and VR experience perceive time going slower than students with more experience. Lastly we showed that students, even though they found the virtual version more frustrating, would rather do that version again instead of the physical version. Also students with more VR experience found the virtual activity more fun than students with less experience.

7 Future Work

Future plans for this work include conducting a clinical versions of this study to get the opinions of patients who are actually undergoing therapy and whether they would want to use VR technologies or not. The target populations for future studies could include patients who are post-stroke, have significant hand pain due to arthritis, or children with cerebral palsy. Besides just gathering their opinions of the technology and comparing the performances between the two versions, we would also be comparing their pain levels between the two versions to see if patients feel less pain performing the virtual version.

We also plan to develop analysis tools to process the data obtained by Leap Motion during the one and five minute sessions. The data and results will be presented in a user interface designed for therapists. We will meet with therapists and discuss the data that is collected and how to visualize the data in a way that is useful to them.

Lastly, we will improve the ability for the person to interact with the virtual environment, mainly the ability to grasp blocks. There are two possible solutions being considered. The first is to improve how the game interprets the pinching motion of the hand while picking up the blocks. The second is to either change sensors or include other sensors to get a more accurate reading of the hand, fingers, and joints.

Acknowledgements. The authors wish to acknowledge the work of Benjamin Chebaa for assisting in the creation of the surveys, Raith Hamzah for developing the background elements to the virtual environment, and to Rebekah Roskens for editing the video. Also, we would like to thank the Dallas VA Research Corporation for providing partial support for this study. This work was also partially supported by the following NSF grants: 1041637, 1035913, 1338118 and 1439645. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

1. Leap Motion Controller SDK. https://developer.leapmotion.com/
2. Tudor, S., Carey, S., Dubey, R.: Development and evaluation of a dynamic virtual reality driving simulator. In: Proceedings of the 8th ACM International Conference on PErvasive Technologies Related to Assistive Environments, pp. 55:1–55:5. ACM, New York (2015)
3. Nakamoto, T., Otaguro, S., Kinoshita, M., Nagahama, M., Ohinishi, K., Ishida, T.: Cooking up an interactive olfactory game display. J. IEEE Comput. Graph. Appl. **28**(1), 75–78 (2008)
4. Bozgeyikli, L., Bozgeyikli, E., Clevenger, M., Raij, A., Alqasemi, R., Sundarrao, S., Dubey, R.: VR4VR: vocational rehabilitation of individuals with disabilities in immersive virtual reality environments. In: Proceedings of the 8th ACM International Conference on PErvasive Technologies Related to Assistive Environments, pp. 54:1–54:4. ACM, New York (2015)
5. Charles, D., Pedlow, K., McDonough, S., Shek, K., Charles, T.: Close range depth sensing cameras for virtual reality based hand rehabilitation. J. Assistive Technol. **8**(3), 138–149 (2014)
6. Sveistrup, H.: Motor rehabilitation using virtual reality. J. NeuroEngineering Rehabil. **1**(1), 1–8 (2004)
7. Mathiowetz, V., Volland, G., Kashman, N., Weber, K.: Adult norms for the box and blocks test of manual dexterity. Am. J. Occup. Ther. **39**(6), 386–391 (1985)
8. Angrilli, A., Cherubini, P., Pavese, A., Manfredini, S.: The influence of affective factors on time perception. Percept. Psychophys. **59**(6), 972–982 (1997)
9. Droit-Volet, S., Brunot, S., Niedenthal, P.M.: Perception of the duration of emotional events. Cogn. Emot. **18**(6), 849–858 (2004)
10. Gable, P.A., Poole, B.D.: Time flies when you're having approach-motivated fun: effects of motivational intensity on time perception. Psychol. Sci. **23**(8), 879–886 (2012)
11. Odgen, R.S., Moore, D., Redfern, L., McGlone, F.: Stroke me for longer this touch feels too short: the effect of pleasant touch on temporal perception. Conscious. Cogn. **36**, 306–313 (2015)
12. Odgen, R.S., Moore, D., Redfern, L., McGlone, F.: The effect of pain and the anticipation of pain on temporal perception: A role for attention and arousal. Cogn. Emot. **29**(5), 910–922 (2015)
13. Fayolle, S., Gil, S., Droit-Volet, S.: Fear and time: fear speeds up the internal clock. Behav. Process. **120**, 135–140 (2015)
14. Keshner, E.: Virtual reality and physical rehabilitation: a new toy or a new research and rehabilitation tool? J. NeuroEngineering Rehabil. **1**(1), 1–2 (2004)
15. Khademi, M., Hondori, H.M., McKenzie, A., Dodakian, L., Lopes, C.V., Cramer, S.C.: Free-hand interaction with leap motion controller for stroke rehabilitation. In: CHI 2014 Extended Abstracts on Human Factors in Computing Systems, pp. 1663–1668. ACM, New York (2014)
16. Bryanton, C., Bosse, J., Brien, M., Mclean, J., McCormick, A., Sveistrup, H.: Feasibility, motivation and selective motor control: virtual reality compared to conventional home exercise in children with cerebral palsy. Cyberpsychology Behavior. **19**(2), 123–128 (2006)
17. Gieser, S.N., Boisselle, A., Makedon, F.: Real-time static gesture recognition for upper extremity rehabilitation using the leap motion. In: Scholz, S.-B., Duffy, G.V. (eds.) DHM 2015. LNCS, vol. 9185, pp. 144–154. Springer, Heidelberg (2015)

18. Broeren, J., Claesson, L., Goude, D., Rydmark, M., Sunnerhagen, K.S.: Virtual rehabilitation in an activity centre for community-dwelling persons with stroke. J. Cerebrovascular Diseases. **26**(3), 289–296 (2008)
19. Saposnik, G., Teasell, R., Mamdani, M., Hall, J., McIlroy, W., Cheung, D., Thorpe, K.E., Cohen, L.G., Bayley, M.: Effectiveness of virtual reality using wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. J. Stroke. **41**(7), 1477–1484 (2010)
20. Cho, S., Kim, W.S., Paik, N.J., Bang, H.: Upper-limb function assessment using VBBTs for stroke patients. IEEE Comput. Graph. Appl. **36**(1), 70–78 (2016)
21. Tobin, S., Grondin, S.: Video games and the perception of very long durations by adolescents. Comput. Hum. Behav. **25**(2), 554–559 (2009)
22. Rau, P.P., Peng, S.Y., Yang, C.C.: Time distortion for expert and novice online game players. Cyberpsychology Behavior. **9**(4), 396–403 (2006)
23. Unity Game Engine. http://unity3d.com/5
24. Box and Blocks Test Instructions. http://www.rehabmeasures.org/PDF%20Library/Box%20and%20Blocks%20Test%20Instructions.pdf