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Extension of an Existing VR Memory Training with Haptic Impressions due to a Haptic Vest

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Abstract: Cognitive performance is an important aspect of life. Not only does thinking enable us to act, there is also an interaction between cognitive performance and mental health. It is therefore increasingly important to train and practice one's cognitive abilities and benefit from brain plasticity. According to Vester's model of learning types visual, auditiv and haptic impression are imporant for learning.
An existing memory training application, which transfers the concept of the game Pairs with personal memories into virtual reality (VR), has now been supplemented with a haptic impression. The original application already establishes the visual and auditory perception channels. With new haptic hardware constantly appearing on the market, the Tactsuit X40 haptic vest from bhaptics has now made it possible to include a third perceptual channel with a wide variation of haptic sensations on various parts of the upper body. Each playing card is associated with an individual image, a piece of music and a vibration pattern. All of which are designed to help the user remember the position of the card. Each of these aspects can be freely enabled and disabled.
The result of this work is an application which aims to find if and how strongly haptic impressions influence memory performance. By taking more types of learning into account, we hope to achieve a better memory training.
A study has been designed to evaluate the specific aspects of the application and is currently being carried out. In addition to the self-generated haptic patterns, it is also possible to generate haptic impulses based on audio sources. These could possibly provide further support in this application.

Keywords: cognitive performance, education, haptic feedback, memory training, virtual reality, VR

1 Introduction

The human brain remains plastic throughout life and is capable of developing and strengthening new synaptic connections. For this reason, cognitive training is important at any age. It helps maintain cognitive performance in the long term, which can improve everyday life and mental health [1].

Based on this theory, a virtual reality (VR) application has already been developed that enables memory training with personal memories (see Fig. 1). For this purpose, the game Pairs is used, which allows the user to memorise motifs and positions in a playful manner. By using biographical images and music, the game, unlike the usual Pairs game, uses both semantic memory, which contains the factual knowledge and also episodic memory, which contains a person's autobiographical memories. This is particularly important for people struggling with the onset of dementia, as it allows them to relive their past and at the same time memory training can alleviate symptoms and delay the progression of the disease [2].

Due to new technologies, which have proliferated in recent years, this application has now been enhanced with a haptic component. This addresses another sense in the process of feeling and acting. The aim is to find out whether haptic elements can further support the thinking process in the virtual world and would be a useful way to complement training applications in VR.

Fig. 1: VR scene from the memory training application

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2 Theoretical Background and Related Work

The process of learning is highly individual. Frederic Vester [3] divided the principle of learning into different types of learning. According to him, there are four different types of learners, which, differentiated by their group, use sensory impressions to grasp and process information. The type of learning is independent of the difficulty of the task, but depends on the individual. In addition to the auditory and visual learning types, which rely on hearing and seeing, and the intellectual learning type, which deals with content, there is the haptic learning type. They learn best by performing actions themselves or by using their sense of touch to examine a model. In this way, they can remember many meaningful features and grasp the information more quickly.

According to the work of F. Hutmacher and C. Kubandner [4], haptic impressions are less affected by habituation than the other perceptual channels, which means that haptic sensations and the memory of them last longer. This can be of particular importance in memory training and help to make faster, greater progress, which in turn increases motivation.

In addition, haptics can increase immersion in a VR application [5–7], which in turn can lead to an increase in learning. According to the work of Mahmoud et al. [5] who compared the response results of a quiz, once in a non-immersive and once in an immersive VR environment. The group using the immersive enviroment performed significantly better on the quiz than the group using a non-immersive VR application.

3 Application

3.1 Hard- and Software

The basic application was developed in the Unity engine (Version 2021.3.3f1) [8]. The programming language used was C#. SteamVR 2.0 was used for the interface to the HTC Vive Pro HMD [9]. For the aspect of tactile experience, the haptic vest Tactsuit X40 was chosen in the context of this work. This does not affect the handling of the previous application, but can provide additional information through haptic feedback:

The Tactsuit X40 [10] haptic vest from bHaptics (see Fig 2) has a total of 40 tactile points. With 20 points on the front and 20 points on the back, vibrotactile feedback can be felt all over the user's upper body. The web application bHaptics Studio from bHaptics allows to create own haptic patterns and integrate them into the Unity application using the SDK. In this way, a wide variety of fundamentally different haptic patterns can be created. The vest also has the ability to independently generate suitable haptic patterns from audio files. The vest is particularly notable for its comparatively low price and universal size. This makes it easy to conduct studies using this technology, as the vest can be adjusted to fit almost any body shape with two buckles on each side.

Fig. 2: bHaptics Tactsuit X-40 [10]

3.2 Concept

This work was based on an existing VR-based memory training [2]. As described, this application uses Vester's learning types in combination with personal memories and individualisation to provide optimal training. In order to add haptic feedback the tactsuit X40 was used, which provides additional information without changing the fundamental structure or functionality of the applications. The basic idea is to complement the autobiographical images associated with specific pieces of music with haptic patterns that can be felt on the wearer's body when the cards are uncovered. In this way, each pair of cards produce the same motif, auditory stimulus and haptic sensation. In the original Pairs game the haptic stimulus is particularly lacking for people who are haptic learners, and they can benefit greatly from this addition.

3.3 Implementation

The SDK developed by bHaptics was used to implement the haptic enhancements. This allows different haptic patterns to

be transferred to the application and played through the vest. This was done at the points where the audio data was played to give a consistent feel throughout the application. For this purpose the bHaptic SDK offers an import which allows access to the bHapticsLibary, so that created haptic patterns from the bHaptics website can be used with the command „bHapticsLibary.Play(name) “.

At the beginning of the game, the user is directed to the desired scene where they are confronted with a table of cards (see Fig 1). These are dynamically generated from locally stored images. These can be uncovered with the controller by pressing a button. As the cards are turned over, the linked music plays. In addition, the haptic impulses generated for this application are accessed from the bHapticLibary and sent to the vest for a haptical impression. If two cards are uncovered, the programme uses IDs to compare whether they are a pair and removes them or covers them up if they are not a pair. Based on the success during the game, the amount of pairs in the next game can increase.

However, as the application was to remain usable without haptic feedback, the application's options menu was extended. Several toggles were added, allowing each perceptual channel to be switched on and off independently (see Fig 3). For example, it is now possible to use only images, only audio or only haptic feedback, or any combination of these. This was particularly important in order to develop a study design that would allow haptics to be evaluated independently of the other aspects.

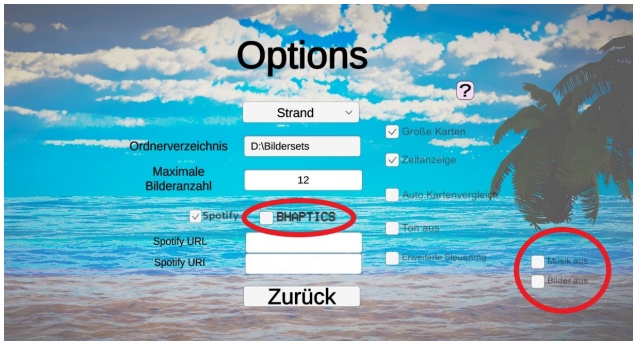

Fig. 3: Additional toggles for all perception channels; Translation: Fields to select an image folder, number of pairs and spotify URL for music. Additional toggles to edit the card size, show a timer, automatically remove cards, background sounds, and advanced controlls.
In red circles: BHaptics = For enabling or disabling the haptical impression; Musik aus = Music off; Bild aus = Images off

3.4 Study Design

For the evaluation of the additional haptic impressions, a suitable study design was developed that takes into account the integration of haptic in the memory process. The basic idea was to test the application once without haptic feedback and once in combination with all perceptual channels. In order to additionally compare the visual impression, which is particularly used in the game Pairs, and the haptics, a third run was designed in which the users were only allowed to use the auditory and haptic feedback to match the cards. This results in the following runs:

- A: Visual and auditory: The original application with biographical images and music.
- B: Haptic and auditory: Application without images. Pairs of cards are matched only by music and haptic patterns.
- C: Visual, auditory and haptic: All available senses are used. Pairs of cards with the same biographical images, pieces of music and haptic patterns.

These three runs are pseudo-randomised for each tester to minimise sequence effects. In order to evaluate the impressions in a meaningful way, different questionnaires are used. On the one hand, a technology consumption questionnaire. This is only intended to determine how experienced the users are with various technologies, especially virtual reality. This is to investigate whether the experience with the technology has an influence on the effect of the application. Followed by two standardised questionnaires on the topics of "immersion and presence" from Witmer and Singer [11] and Igroup [12]. As mentioned above, an immersive VR application can enhance learning. Therefore, it is important to collect the impression in a standardised way.

This is complemented by specific questions about the individual channels of perception. In particular about the feel and effect of the vest. Additional questions from the questionnaire of Cappello et al. [13] for the evaluation of the tactile impression.

Currently, a usability study is taking place with a total of 20 participants. In addition to testing the usability, this study is intended to provide indications of the subject group size needed for the upcoming main study. It can also give initial indications of the effect of the haptic extension. While the evaluation of this study is still underway, tendencies point towards the haptic impression being rated as helpful, but less relevant than visual or audio feedback. Additionally, the vest was well accepted. Neither in comfort nor in mobility were any problems reported within the VR.

4 Conclusion and Future Works

The integration of the Tactsuit X40 from bHaptics did not require any restructuring of the base programm. The SDK is clearly laid out and offers a thorough introduction and detailed documentation. The vest's fit makes it suitable for a wide range of body types, and so far there have been no problems in terms of comfort or restricted movement. With a battery life of around 18 hours, it is possible to complete several tests in a row without any problems. The haptic pulses are strong enough to be worn over clothing, so there are no hygiene issues. Based on these results obtained during the implementation, it can be assumed that some other commercially available haptic devices also offer similar advantages and can be integrated into existing applications. Whether this is also a useful extension of applications, especially memory training, needs to be shown through studies. After the current usability study a long-term study on the effectiveness of the haptic extension and it's influence on the memorization process should be carried out. If haptic impulses improve the effectiveness of the application, then another topic for future research could be to investigate whether haptic impulses generated from the audio files contribute more to the learning effect, than independent haptic impulses.

References

[1] Klein E, Willmes K, Bieck SM, Bloechle J, Moeller K. White matter neuro-plasticity in mental arithmetic: Changes in hippocampal connectivity following arithmetic drill training. Cortex. 2019 May;114:115-123. doi: 10.1016/j .cortex.2018.05.017 . Epub 2018 Jun 7. PMID: 29961540 .

[2] Vanessa Schmücker et al., "Customizable Memory Training in Virtual Reality with Personal Memoirs," 2021 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR), Taichung, Taiwan, 2021, pp. 189-193, doi: 10.1109/AIVR52153.2021.00042

[3] Vester, F. (2021). Denken, "Lernen, Vergessen was geht in unserem kopf vor, Wie lernt das gehirn, und wann laesst es uns im Stich?". dtv., 3423330457

[4] Hutmacher F, Kuhbandner C. Long-Term Memory for Haptically Explored Objects: Fidelity, Durability, Incidental Encoding, and Cross-Modal Transfer. Psychol Sci. 2018 Dec;29(12):2031-2038. doi: 10.1177/0956797618803644

[5] Khadija Mahmoud, Isaac Harris, Husam Yassin, Thomas J. Hurkxkens, Omar K. Matar, Nitesh Bhatia, and Irene Kalkanis. 2020. Does Immersive VR Increase Learning Gain When Compared to a Non-immersive VR Learning Experience? In Learning and Collaboration Technologies. Human and Technology Ecosystems: 7th International Conference, LCT 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II. Springer-Verlag, Berlin, Heidelberg, 480–498. https://doi.org/10.1007/978-3-030-50506-6 _33

[6] Collins Jonny, Regenbrecht Holger, Langlotz Tobias. (2021). Expertise and Experience in VR-supported learning: Achieving a deep non-verbal comprehension of four-dimensional space. International Journal of Human-Computer Studies. 152. 102649.10.1016/j.ijhcs.2021.102649.

[7] I. Maheshwari and P. Maheshwari, "Effectiveness of Immersive VR in STEM Education," 2020 Seventh International Conference on Information Technology Trends (ITT), Abu Dhabi, United Arab Emirates, 2020, pp. 7-12, doi: 10.1109/ITT51279.2020.9320779

[8] "Unity Real-Time Development Platform | 3D, 2D VR & AR Engine", https://unity.com/, 24.03.2023.

[9] "VIVE Pro Full Kit | VIVE European Union", https://www.vive.com/eu/product/vive-pro-full-kit/, 27.03.2023.

[10] "Most Advanced Full Body Haptic Suit - bHaptics TactSuit", bHaptics, https://www.bhaptics.com/tactsuit/tactsuit-x40, 27.03.2023.

[11] Witmer, Bob G.; Singer, Michael J. (1998). Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence: Teleoperators and Virtual Environments, 7(3), 225–240. doi:10.1162/105474698565686

[12] "igroup presence questionnaire (IPQ) Item Download | igroup.org – project consortium", http://www.igroup.org/pq/ipq/download.php, 27.03.2023.

[13] Cappello Leonardo, Alghilan Waleed , Gabardi Massimiliano, Leonardis Daniele et al. (2020). Continuous supplementary tactile feedback can be applied (and then removed) to enhance precision manipulation. Journal of NeuroEngineering and Rehabilitation. 17. 10.1186/s12984-020-00736-9