https://nbn-resolving.org/urn:nbn:de:bsz:ch1-qucosa2-806704

Influence of the Vergence-Accommodation-Conflict by Using HMDs with Augmented Reality for Sport and Exercises – First Results

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Abstract

To improve the performance and capabilities of athletes, augmented reality could play an important role in exercise training. During training, these technologies support athletes in analyzing their training over all phases. Regardless of all potential advantages, the vergence-accommodation-conflict (VAC) could affect the effectiveness of training and performance. This work is aimed to evaluate the effect of VAC in different conditions.

Keywords: vergence-accommodation-conflict, augmented reality, HMD, sport sciences, sports education, training, performance

Introduction

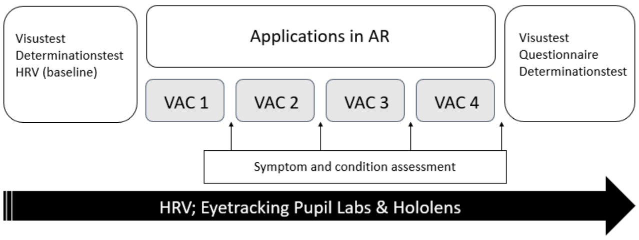
Due to the multiple ways of generating environmental and perceptual stimuli, the application and use of virtual and augmented reality (VR and AR) is gaining more and more popularity. To enhance and extend the efficiency of training methods, learning experiences and realize novel learning exercise scenarios, these technologies are also increasingly considered in the context of exercises and sports science (Loila & Orciuoli, 2019). Existing AR solutions are mainly used for enhancing training sessions, observing athletes' data or providing additional information during training. This allows the athletes and also patients in their rehabilitation phase to improve their specific physical behaviour. By adding relevant goals, the monotonous parts of the training should become more attractive and social cooperation should be promoted (Kajastila und Hämäläinen, 2014). Improving the mental, perceptual skills, coordination, and further reaction times, the AR-based devices could be useful to reduce errors (Loila & Orciuoli, 2019).

However, besides the potential to create new supporting training settings and generate potential solutions for enhancing performance, head- or helmet-mounted displays (HMDs) also have drawbacks in this context that could affect training success. Thus, the vergence-accommodation conflict (VAC) is a well-known phenomenon in this context (Cakmakci & Rolland, 2006). Especially women are prone to symptoms of VAC (Grassini & Laumann, 2021). This effect is exacerbated in AR when a relatively close real object is augmented by additional virtual information (Duchesne & Coubard, 2021). Furthermore, visual processes responsible for clear and simple binocular vision can thus interfere with cognitive processes and attentional conduction, thus affecting learning and training success in its entirety (Daniel & Kapoula, 2019). Therefore, this study aims to investigate the influence of such AR headsets with simple virtual and real objects on vergence, well-being as well as concentration ability of students. Based on the findings, training and exercise environments can be designed in a method-appropriate manner without the success of performance being influenced by the VAC. In this study, we focus on the first results for the well-being and possible symptoms, caused by being in an environment with AR-elements.

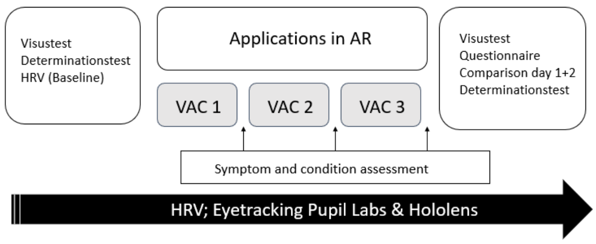
Methods

A total of 45 healthy subjects (gender: 28 female, 17 male, 0 divers; age *M* = 23.26, *SD* = 3.10) underwent the experiment. Subjects had to have the normal or corrected-to-normal vision, which was checked in advance with a visual acuity chart, followed by the baseline measurement of HRV and the applications in AR. Data on gaze behavior using eye trackers were collected continuously throughout the usage of the AR-application. In addition, symptoms and sensitivities were queried after each app (VAC 1, 2, 3, and 4) (Fig. 1). The order of the apps was randomized using a randomization list. As HDM, we used the HoloLens 2 (Microsoft Corporation, Redmond, Washington, USA).

(a)



(b)



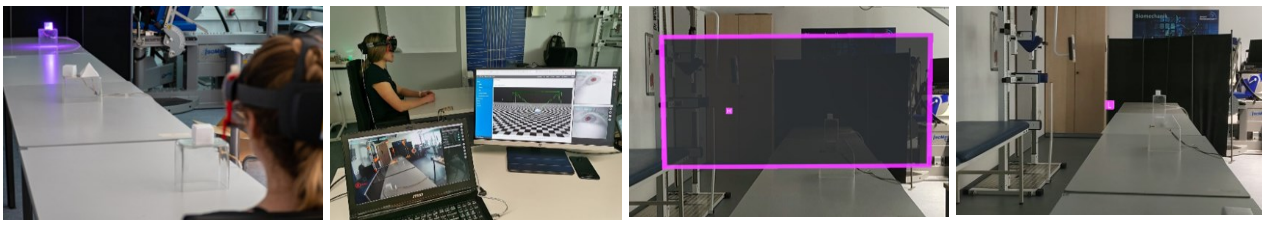


Fig. 1 Set-up and schematic representation of the study procedure of day 1 (a) and day 2 (b)

We developed four types of interventions for the 1st day with variable distances: VAC 1: display/watching of real and virtual boxes; VAC 2: watching letters and numbers with sequential writing; VAC 3: boxes in motion: reading sequence at different distances; VAC 4: boxes in motion with constantly changing distance; and three types of interventions for the 2nd day analog to day 1 (VAC 1-3), but with a fixed distance. On day two all subjects were randomly assigned to the two groups with different distances (distance 2.5 m: *n* = 23; age: *M* = 23.48, *SD* = 3.66 / distance 0.7 m: *n* = 22; age: *M* = 22.82, *SD* = 2.01). This assignment was done single-blinded, using a randomization list. To measure the symptoms after the intervention, we used the adaption of Visual Fatigue Questionnaire (VFQ) (Bangor, 2000; Spilski et al., 2019), which consists of 17 items with a 5 Likert scale (1-5). During the intervention, eye tracking data will be collected to calculate the real vergence angle (Daniel & Kapoula, 2019), as well as heart rate variability (HRV) to measure stress. The real vergence angle data are then compared with the mathematically postulated vergence angle, and the HRV is compared with baseline measurements. Symptoms of VAC are additionally queried via two symptom questionnaires.

Results

Gender specific differences were only found for the item “Ich habe Kopfschmerzen" (I've headaches) (F(1,43) = 5.41, p = .02, $\eta_p{}^2$ = .1118). On day 2, when the subjects were randomly assigned to the two distance groups, a significant difference was only found for the item "Mein Gesicht ist schweißnass" (my face is wet with sweat) (F(1,43) = 4.26, p = .04; $\eta_p{}^2$ = .09). The multivariate comparisons showed no significance between the groups and the two test days.

Discussion

Our first results, which indicate almost no symptoms when using the Microsoft HoloLens, confirm the findings of Vovk, Wild, Guest & Kuula (2018). One explanation for the significant result from day 1 can be found in the changing distances on day 1. Thus, the VAC is provoked by continuous refocusing and accommodation. This could be the first indication of how training and exercise sessions can be designed and which arrangement (e.g. fixed distances) of virtual objects is more suitable.

At this point, we want to point out the pending analysis of the eye tracking and HRV data across the complete cohort and the individual level. During the execution of the experiment, it became apparent that consideration of individual cases could be interesting in this context. Nevertheless, the study contains a few limitations. For example, the subjects completed the questionnaire only a few minutes after the intervention in the AR environment, which means that delayed symptoms are no longer recorded. In addition, the subjects were in the AR environment for 30 minutes. The after-effects of prolonged exposure to AR, especially in connection with sporting activities, are still unclear. Further research should aim to evaluate AR to induce an external associative focus and investigate its effectiveness in enhancing performance and physical capabilities.

Summarising, AR can enable situations that are not readily available in physical reality. This includes training and realistic preparation for possible stressful situations in competition, as well as direct feedback to improve individual skills and movements. Based on the insights gained, training and exercise environments can be designed in a method-appropriate way without success being influenced by the VAC.

Conflict of interest: The authors declare no conflict of interest.

Funding: The project Health.Holo.Lab as a sub-project of "U.EDU: Unified Education – Medienbildung entlang der Lehrerbildungskette" is part of the “Qualitätsoffensive Lehrerbildung”, a joint initiative of the Federal Government and the Länder which aims to improve the quality of teacher training. The program is funded by the Federal Ministry of Education and Research. The authors are responsible for the content of this publication. BMBF [01JA2029].

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