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Influence of Virtual Shoe Formality on Gait and Cognitive Performance in a VR Walking Task

Sebastian Oberdörfer*[*]
Human-Computer Interaction
University of Würzburg

Sandra Birnstiel*[†]
Gamification Research Group
Friedrich-Alexander-Universität
Erlangen-Nürnberg

Marc Erich Latoschik[‡]
Human-Computer Interaction
University of Würzburg

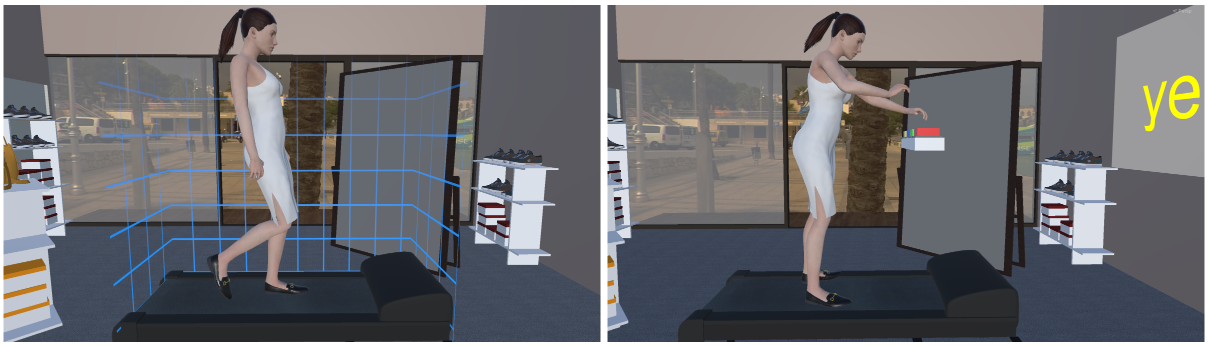

Figure 1: After a walking task in VR using different virtual shoes, participants completed a Stroop task.

Abstract

Depending on their formality, clothes do not only change one's appearance, but can also influence behavior and cognitive processes. Shoes are a special aspect of an outfit. Besides coming in various degrees of formality, their structure can affect human gait. Avatars used to embody users in immersive Virtual Reality (VR) can wear any kind of clothing. According to the Proteus Effect, the appearance of a user's avatar can influence their behavior. Users change their behavior in accordance to the expected behavior of the avatar. In our study, we embody 39 participants with a generic avatar of the user's gender wearing three different pairs of shoes as within condition. The shoes differ in degree of formality. We measure the gait during a 2-minute walking task during which participants wore the same real shoe and assess selective attention using the Stroop task. Our results show significant differences in gait between the tested virtual shoe pairs. We found small effects between the three shoe conditions with respect to selective attention. However, we found no significant differences with respect to correct items and response time in the Stroop task. Thus, our results indicate that virtual shoes are accepted by users and, although not eliciting any physical constraints, lead to changes in gait. This suggests that users not only adjust personal behavior according to the Proteus Effect, but also are affected by virtual biomechanical constraints. Also, our results suggest a potential influence of virtual clothing on cognitive performance.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Human computer interaction (HCI)—Empirical studies in HCI

[*]e-mail: sebastian.oberdoerfer@uni-wuerzburg.de
[†]e-mail: sandra.birnstiel@fau.de
[‡]e-mail: marc.latoschik@uni-wuerzburg.de

*These authors contributed equally to this work and share first authorship.

1 Introduction

Clothes allow people to express themselves, to dress appropriately for a given social situation, and to even boost their cognitive abilities by applying certain meaning to outfits [1]. A special factor of the overall outfit are shoes. Besides dressing up or dressing down the worn outfit, they also can influence the behavior of wearers by either biomechanically forcing them into a certain gait [33] or influencing their self-esteem and confidence.

Immersive Virtual Reality (VR) not only allows users to experience emotionally affective virtual environments [54], but also to embody an avatar that can elicit specific characteristics or wear particular clothes. Immersion is defined as "*the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant*" [51]. Immersion further encompasses the possible user actions within a given system [49] like grabbing and manipulating virtual objects. The subjective acceptance of the virtual environment as one's current location is described with *presence* [49]. Presence is influenced by the degree of immersion [50, 58] and the perceived realness of a virtual experience [48]. Embodiment describes the feeling of being inside an avatar, owning and controlling it [18, 23]. According to the Proteus Effect, a user confirms their behavior to the expected behavior of their digital self-representation [59].

Taken together, it is possible that a user's behavior changes based on the clothes their digital self wears. While this was already demonstrated for sexualized outfits [11], it is still unclear whether even shoes can evoke a behavioral change. Since the design of shoes cannot only change a wearer's formality, but also gait like when wearing high-heels [10, 47], it is important to investigate the effects of virtual shoes on two levels. Following the theory of Enclothed-Cognition [1], a subject's cognitive abilities must be analyzed. At the same time, analyzing the gait of a subject wearing different types of virtual shoes might reveal insights into the acceptance and internalization of physical constraints on one's body.

Contribution

This paper presents the results of a user study investigating the effects of shoe formality on gait and selective attention. We embody 39 participants with a generic avatar of the users' gender wearing three different pairs of shoes in randomized order. The shoes differ in degree of formality. We measure gait during a 2-minute walking task in which participants always wore the same real shoe, and examine selective attention using the Stroop task as displayed in Fig. 1. Our results show significant differences with respect to gait but not to selective attention between the different pairs of shoes. However, we found small effects when analyzing the number of correctly selected items and response time between the three shoe conditions. Thus, our results indicate that virtual shoes are accepted by users and, although they cannot induce real physical constraints, they lead to changes in gait. This suggests that users not only adapt their personal behavior as described by the Proteus Effect, but are also influenced by virtual biomechanical constraints of their outfits. Also, our results suggest a potential influence of virtual clothing on cognitive performance.

2 Theoretical Background

The presentation of users is an important VR factor. Users are (1) not represented at all, (2) represented by 3D models of their game controllers or of human hands when aiming for a *minimal embodiment*, or (3) represented by an avatar when targeting a *full embodiment* [35]. The design space between minimal and full embodiment also allows for a partial embodiment such as representing a user with head, torso and hands, only [28]. The quale of embodiment consists of the subconcepts virtual body ownership (VBO), agency, and self-location. VBO is the subjective experience of assigning an avatar to oneself, agency describes the subjective experience of controlling it, and self-location is the perception of being in one place with the avatar [23]. VBO can be increased by providing photorealistic or even personalized avatars [58].

The design and overall appearance of an avatar can achieve perceptual or behavioral changes [27, 43]. According to the Proteus Effect, users start to elicit characteristics and stereotypes they associate with the avatar they are embodied with. These adopted behaviors even influence their virtual social interactions. The resulting effects have a wide range like different movement patterns in a drumming task when a light-skinned user is embodied in a dark-skinned avatar [22], a lower walking speed when embodied in an elderly avatar [42], and the perception of objects being larger when embodied as a child [3], but also in a reduction of implicit racial bias and hence a change in interpersonal attitudes [4, 39]. The Proteus Effect even applies to physical activities. Avatars associated with a higher fitness level can reduce perceived effort and heart rate during physical activity in VR [25] and avatars with a more pronounced muscular appearance can increase grip strength of male users [26]. The behavioral changes are caused not only by the avatar's body, but also by the clothes or appearance. For instance, avatars dressed in more sexualized outfits lead to more body-related thoughts [11] and sweaty avatars can reduce the perceived intensity and exertion of a cycling task compared to non-sweaty avatars [24]. Finally, even avatars that differ from normal human bodies evoke behavioral changes such as behaving like a gorilla [8] or learning to control a virtual tail [55].

2.1 Clothing

Clothing can influence the behavior of the wearer. In one study, for example, participants in a shopping task tried on clothes that stimulated self-objectification due to the characteristic of the clothing being form-fitting or not. Participants who tried on a form-fitting swimwear performed worse in a subsequent math test than those who tried a sweater [13]. These results were evident in men and women of all ethnicities [15]. In a similar study, it was shown that eating behavior can also be influenced by form-fitting clothing. In this study, homosexual men ate significantly less of a snack when they wore tight swim trunks instead of a sweater in a shopping task [30]. Moreover, it has been found that the behavior of professional athletes in black uniforms is not only perceived as more aggressive than players in uniforms of a different color, but athletes in black also receive more penalties for aggressive behavior [12].

Clothing also has an impact on the cognitive abilities of the wearer, for which the term Enclothed-Cognition was coined [1]. This is the case when the clothing has a symbolic meaning for the wearers while they are wearing it. In the experiment of Adam and Galinsky [1], subjects wore a white coat that could be associated with different properties, depending on its description as a painter's or doctor's coat. Subjects performed better in an attention task when they associated the coat with a doctor's coat, which symbolized carefulness and attention through its scientific orientation [1]. Formal clothing also has a symbolic meaning for wearers. People feel more competent and productive when wearing formal clothing, which is usually associated with a business context. In contrast, casual clothing would make people describe themselves as more relaxed and friendly [2, 40]. Even improved abstract reasoning is demonstrated by wearing formal clothing [52]. Competence and productivity, but also abstract thinking, require good cognitive performance in, for example, attention-related tasks. Therefore, the cognitive performance of the wearer can also vary with the formality of the clothing, especially attention.

While clothing generally determines the style of one's attire, shoes are responsible for the final appearance. For instance, wearing a suit and running shoes dresses down the formality of the suit. Vice-versa, wearing a polo-shirt, chinos, and dress shoes results in a more formal appearance. In addition, physical shoes can affect our gait cycle [10, 47]. Following the concept of the Proteus Effect, it is possible that users will accept virtual shoes as their real shoes and even change their gait based on the characteristics of the virtual shoe. Hence, investigating the effects of wearing different types of virtual shoes cannot only reveal insights into our cognitive behavior but also continue the ongoing investigation of the effects of embodiment.

2.2 Cognitive Performance

Cognitive abilities are the abilities of humans to perceive and process signals from the environment and is thus the sum of all thinking and perception processes and their mental results [14]. This includes abilities such as attention, perception, thinking, remembering, understanding, and problem solving. Cognitive performance describes the effectiveness of cognitive abilities, where better cognitive performance means more effective cognitive abilities.

Human cognitive abilities are diverse, so there are many different methods to measure cognitive performance. IQ tests, as one option, often involve many different abilities, but are time-consuming and costly. Therefore, methods that only target specific cognitive abilities are usually more appropriate. Thus, measuring cognitive performance can also be done by using math tasks that primarily cover skills related to reasoning and problem solving. For example, math tasks have been used to examine the change in performance due to form-fitting clothing [15]. However, with such tests, it is important to chose an appropriate level of difficulty and appropriate completion time in order to create a valid test.

As a widely used and simple variant to measure selective attention as a cognitive ability, a Stroop test is often used. For instance, it was used in one of the experiments to measure cognitive performance while wearing a lab or painter's coat [1]. Stroop tests measure the Stroop effect, which describes the delay in reaction time to congruent and incongruent stimuli [29, 56]. In a Stroop test, the font color of a written word must be named or logged, whereas the content of the word is irrelevant. A distinction is made between congruent stimuli, in which the content and color of the word match, and incongruent stimuli, in which the color and content do not match. Besides measuring selective attention, such tests can measure cognitive processing speed or cognitive flexibility [16].

Stroop tests have also been used in VR applications [31, 38]. In the original version, items on printed cards are read aloud. For the implementation in VR, there are already some approaches to logging in the answers from subjects to presented items. One possibility is to let the user select the answers by pressing diegetic buttons, each representing the possible font colors of the items [32]. An alternative is to present auditorily all possible answers to each item. In this variant, the user logs his answer by awaiting the word from the auditory voice to choose. Once they hear the desired word, they press a button on the controller to select their answer [31].

2.3 Shoes and Gait

Morris et al. [33] analyzed the gait of women wearing high-heeled shoes in a laboratory study. From a heel height of about 5 cm, the shoes change the mechanics of walking [10, 47]. Twelve women walked in flat shoes and high-heels on a treadmill for four minutes at 1% incline and 4 km/h respectively. Their gait was captured using an optoelectronic motion capture system and retroflective markers placed on the participants' bodies. Finally, data of five consecutive gait cycles at the end of a walking interval were averaged to analyze time and joint angle data. In particular, they assessed knee flexion relativ to the static joint and various hip angles as well as stride length, duration, and frequency. The study revealed that women in high-heels take shorter, faster steps, bend their knees and hips less, but rotate and tilt their hips more than in flat shoes.

Following this approach allows for an analysis of potential changes in the gait of users when wearing different types of virtual shoes.

3 System

We embedded the evaluation of the effects of wearing virtual shoes in a cover story to avoid priming the participants. In particular, we designed a virtual shoe store and told the participants that they would be trying on new shoes. To allow them to test walk the virtual shoes, we used a treadmill placed inside the tracking area of our motion capture system. The shoe store followed the design of a small boutique located at a harbor promenade which was visible through large windows. In the center of the store, we placed a 3D model of a treadmill. The model was adjusted with respect to the location and dimensions of the physical treadmill. To ensure safety, we displayed a Chaperone system around the treadmill during phases of walking as displayed in Fig. 1 left. Besides the treadmill, the store featured a large side and frontal mirror as well as shelves full of various shoes and shoe boxes standing at the walls. The system disabled the mirrors during the walking task and Stroop test to avoid continuous priming, which could cause participants to adjust their behavior according to their virtual mirror image. Therefore, the mirrors were only enabled during familiarization and priming with the respective shoe pair.

Our VR system represented the participants with a realistic generic avatar created with the o3n asset [34]. A personalized photorealistic avatar might have resulted in a higher acceptance of the virtual body, but could also have caused confounds due to a potential mismatch of the shoe 3D models and the avatar itself. Using the o3n asset allowed us to dress the avatar with virtual shoes specifically adjusted to it. Also, generic avatars ensured that the resulting conditions only differed with respect to the virtual shoes. We scaled the size of the avatar according to the subject's height. Following the approach of Morris et al. [33], we used a motion capture system to track the gait cycle of the participants by logging their movements for a follow-up analysis. This approach further enabled us to use the motion capture data stream to animate the avatars.

We developed the VR system with Unity 2020.1.4 [57]. We used the OptiTrack motion capture system [36] and streamed the data to Unity using the OptiTrack plugin [37].

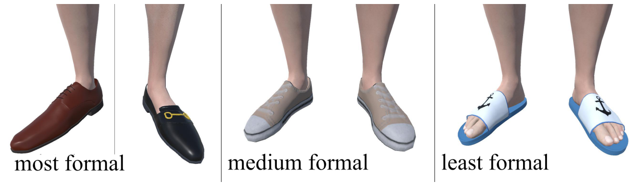

Figure 2: An overview of the tested shoes: Highly formal dress shoes (left; brown dress shoe worn by males, black loafer worn by females), medium formal sneaker (mid), and a less formal bathing shoe (right).

3.1 Shoe Design

To investigate the effect of different shoes on user behavior, we chose to use three pairs of shoes with different formal styles for one male and one female avatar. We based the visual design on generally applicable dress codes for different styles of workplace attire [19, 46]. For the most formal level, we followed common dress codes for formal business occasions. Since different shoes are usually recommended for different genders, we followed these guidelines and created different pairs of shoes for the male and female avatar. Therefore we created brown dress shoes for the male avatar and black loafers with golden details for the female avatar.

For the medium formal level, we chose beige sneakers suitable for a casual occasion. For the least formal level, we chose shoes clearly attributable to the leisure time context, which were blue and white bathing shoes with an anchor motif on top.

We created the shoes for the most and least formal level in Blender 2.8 and used prefabricated ones for the medium formal level from the o3n asset. The shoes are displayed in Fig. 2.

3.2 Avatar Clothing

To ensure that the formality of the appearance is only dependent on the type of shoes and not influenced by the rest of the avatars' clothing, we wanted to find a neutral outfit each for a male and a female generic avatar. In an online questionnaire, subjects were asked to assess and comment on different outfits of the avatars. For the male and female avatars, we created five different outfit combinations each, which were shown individually in the questionnaire with one of each of the three pairs of shoes combined in a picture.

After a first evaluation round, we adjusted the outfits based on the feedback received. Subsequently, we repeated the online study with updated pictures of the avatars. Based on the results of this final study, we selected a white dress for the female avatar and a combination of white shirt and jeans for the male avatar. Both outfits were well received with respect to harmony between clothes and shoes. Also, both outfits resulted in a gradation of formality based on the shoes used.

A repeated measures ANOVA shows that the outfits were perceived significantly differently in terms of formality dependent on the shoe pairs, $F(2,34) = 95.00, p < .001, \eta^2 = 0.66$. Post hoc tests with Bonferroni correction show that the most formal shoes ($M = 6.73, SD = 0.79$) were perceived to be significantly more formal than the medium formal shoes ($M = 5.01, SD = 1.12$) and the medium formal shoes were perceived to be significantly more formal than the least formal shoes ($M = 2.81, SD = 1.52$), $p < .001$.

3.3 Stroop Task

We based the design of the Stroop test on the work of Mevlevioğlu et al. [32] and the procedure on the work of Adam and Galinsky [1]. On the wall in front of the subject, the items were shown on a display. Each item consisted of a word, for example *yellow*, written either in yellow, blue, green or red. Buttons appeared directly in front of the avatar. Each button stood for one of the four possible font colors, as can be seen in Fig. 1 right and Fig. 3. Using the motion

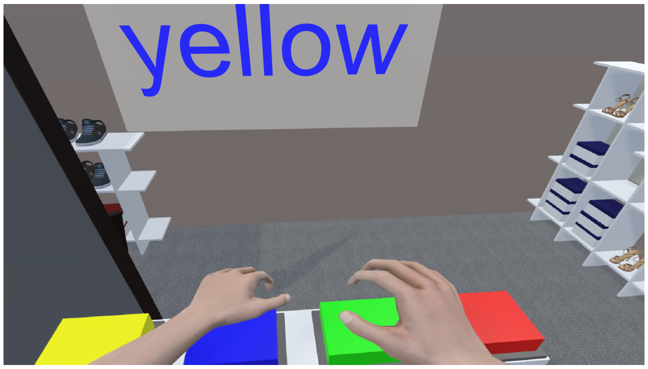

Figure 3: During the Stroop task, participants selected the font color of the displayed word using the four buttons.

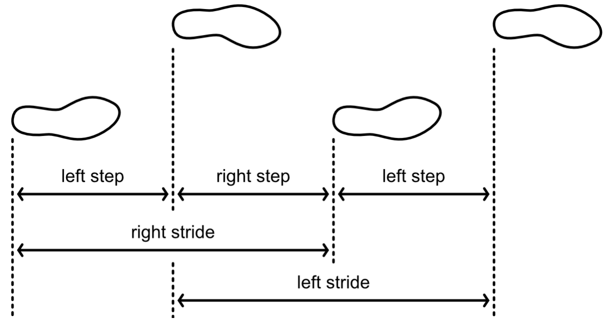

Figure 4: We defined a stride as interval between two heel strikes of the right foot.

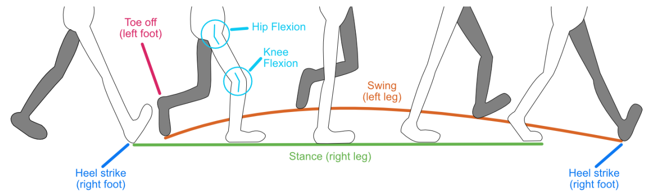

Figure 5: The schematic illustrates a human walk cycle. We computed the flexion of the hip and knee at each phase of the gait.

capture system, the buttons could be selected by pressing them with any of their hands or even both of them. As soon as a response was logged in, the next item appeared. Participants were asked to enter what color the word on the display in front of them was written in as quickly as possible by pressing buttons. A total of 50 items were displayed. Half of them were congruent items, where word and color matched, the other half were incongruent items. The order of the items was random. When answering the Stroop test, the time taken to log the answer and the correctness of the answer were recorded for each item. The execution of the test was explained auditorily each time it was administered.

For practice, after the first test walk in VR without virtual shoes, the test subjects performed a short exercise session of the test in which only 10 items were answered. This was to avoid uncertainties in the actual experiment. For better understanding, congruent items were first answered followed by incongruent items.

4 Study Design

Based on the considerations in Sect. 2 and Sect. 3, we expect that subjects in the designed VR environment will accept their virtual appearance in VR due to the Proteus Effect. Therefore, we expect that stereotypical expectations about the changed level of formality of shoes will be reflected in users' more formal behavior and improved cognitive performance with more formal shoes imitating a more professional appearance. We therefore adopt the following hypotheses:

H1: The more formal the visual appearance in VR that is created by the virtual pair of shoes, the more formally the participants will walk. This will be reflected in multiple factors of human gait.

H2: The more formal the visual appearance in VR that is created by the virtual pair of shoes, the better the cognitive performance of the participants will be.

We tested the hypotheses by conducting a user study following a mixed-subject design, considering the type of virtual shoes as within and the gender of the participants as between factor. The independent variable of virtual shoes was manipulated at three levels from most to least formal virtual shoes described in Sect. 3.1. In reality, participants wore the same flat shoes throughout the experiment. The order of the conditions was counterbalanced.

Following the approach of Morris et al. [33] for testing changes in human gait, we make a decision about a joint null hypothesis after rejecting *all* of it constituent null hypotheses, thus conducting *conjunction testing* [45]. In particular, we expect changes with respect to stride duration, stride length, and hip as well as knee flexion. Hence, for H1 to be accepted, all constituent hypotheses must be accepted.

4.1 Safety and Ethics

We implemented an elastic safety belt as described by Birnstiel et al. [6] to limit the risk of injury when walking on a treadmill in VR. Also, we trained with the participants to walk on the treadmill while wearing the HMD. Our study was approved by the Human Computer Media institutional ethics review board of the University of Würzburg.

4.2 Measures

As dependent variables, we considered the gait pattern of the walking behavior in VR and cognitive performance. Both variables were measured in VR after the priming of the participant with the respective shoe pair. This allowed for a direct assessment of the effect of the changed embodiment. The mirror was disabled during measurement to avoid any effects of continuous priming, as it was expected that the priming effect would still persist at this stage. Additionally, we recorded supplementary measures to control for potential affecting factors. This resulted in the following measurements:

4.2.1 Demography

In a self-designed questionnaire, we collected demographic data of the test subjects. This includes their height, age, gender and occupation. We also collected the frequency of use of various media, such as computers, the internet, computer games, smartphones, AR and VR. In addition, we asked about possible relevant limitations of the participants, such as visual and hearing impairments, language skills, and handedness.

4.2.2 Gait Pattern

To measure and analyze the walking behavior, we followed the approach of Morris et al. [33]. Using OptiTrack, we recorded the participant's movements while walking on the treadmill for follow-up analyses. To measure the participant's steps, we attached colliders to the toes and heels of the two avatars in Unity. Only 5 strides per participant at the end of the walking interval were included in the statistical analysis. Following their study design, we assumed that the subjects were already walking uniformly on the treadmill with the respective shoes at this stage.

We computed the length in meters and duration in seconds of each stride, which we defined as interval between two heel strikes of the right foot as displayed in Fig. 4. We determined the heel strike based on the spatial and temporal collision of the heel with the treadmill model and the toe-off by the end of the collision of the toes and the ground. In addition, various angles of knee and hip joints were recorded in degrees at different stages in the gait cycle as displayed in Fig. 5. The knee flexion was determined relative to the static leg, which was defined at the start of the VR application during a T-pose of the subject. For each heel strike and toe-off, the flexion of knee and hip were calculated for both legs, respectively. In addition, the maximum flexion of knee and hip for both legs was determined in two different stages: stance and swing. The stance stage is the time interval in which a foot is in contact with the ground. It begins with heel strike and ends with toe-off of the same foot. The swing stage, on the other hand, is the temporal interval in which a foot is in swing and thus has no contact with the ground. It begins with toe-off and ends with heel strike of the same foot. Additionally, the difference in hip tilt and hip rotation during each stride was calculated. Furthermore, we recorded the difference in shoulder rotation per stride due to possible changes in upper body posture. Other measurements of the upper body could not be reliably recorded due to the subjects' freedom of movement during walking.

4.2.3 Cognitive Performance

In order to assess cognitive performance, especially with regard to selective attention, in different pairs of shoes, subjects performed a Stroop test while wearing each virtual pair of shoes in VR.

4.2.4 Simulator Sickness

We further included a measure of cybersickness, which served as a control variable to ensure that potential effects on dependent variables were not a result of confounding by developing sickness during the intervention period. We assessed the cybersickness before and after the experiment using the Simulator Sickness Questionnaire (SSQ) [20]. The SSQ scales range from 0 to 3. The total score was calculated as described by Kennedy et al. [20]. Low scores indicate low sickness.

4.2.5 Qualitative Measures

We included a qualitative question at the end of the questionnaire to evaluate the experience. In particular, we asked which of the shoes felt most comfortable during the walking phases.

4.3 Manipulation Check

We included a manipulation check after the participants received a new pair of shoes and got familiar with them. In particular, we asked the participants to rate the level of formality of their appearance on a scale from 1 (not at all) to 5 (very formal). The scale was presented as buttons in front of the subject and the answer was entered by button press.

4.4 Procedure

First, the participant was welcomed and received a short information sheet on the experiment and a consent form to read and sign. Then, the subject put on a motion capture suit and placed the markers on it in order to start the experiment directly after completing the pre-questionnaire. The questionnaire was completed on a separate PC and included demographic data and the SSQ. This was followed by an information text about the procedure of the experiment. Subsequently, three stages on the treadmill followed:

1 The participant entered the treadmill, the safety precautions were explained and implemented as explained in Sect. 4.1. The subject did not leave the treadmill until the 3rd stage was completed. Subsequently, a test walk on the treadmill started, for which the experimenter counted a countdown loudly and started the treadmill, so that the participant could easily estimate the start of movement. After 2 minutes of walking, the experimenter counted down loudly again and stopped the treadmill.

2 The subject put on the VR headset and found themself in the virtual shoe store. There they could observe their embodiment without shoes in a mirror while following auditory instructions to familiarize themself with the body. Then a trial version of the manipulation check was performed. The mirror was disabled after the virtual appearance was primed. Next, the treadmill was started and stopped after 2 minutes, as described in stage 1. A short trial version of the Stroop task was performed.

3 In this stage, the subject's avatar was fitted with one of the pairs of shoes, visible in the enabled mirror. An audio instruction to familiarize with the shoes followed. The remaining procedure is similar to step 2, consisting of a manipulation check, treadmill walk and Stroop test consisting of 50 items. This procedure was repeated for each shoe pair.

Subsequently, the participant answered the post-questionnaire on the PC consisting of SSQ and qualitative question. A disclosure text appeared at the end of the questionnaire. Each study session lasted about 1.25 hours.

The study took place during the COVID-19 pandemic. To ensure for protection and hygiene, we took the following precautions. (1) Each participant was required to constantly wear a mask. (2) The experimenter was required to constantly wear a mask. (3) The experimenter and the participant were required to keep at least a distance of 1.5 meters. (4) All touched surfaces and used devices, like HMD and keyboard, had to be cleaned with a disinfectant product after each experimental trial.

4.5 Apparatus

The experimental setup consisted of a computer (CPU: Intel i7-9700K @3.6GHz, RAM: 32GB, GPU: NVIDIA GeForce RTX 2070 SUPER), an HTC Vive Pro (1440x1600 px resolution per eye, 110° FOV), the OptiTrack motion capture system, and a treadmill. The OptiTrack motion capture system, consisting of 18 Prime^{x}13 infrared cameras, was used to track the subjects' movements. We used the baseline 37-marker setup for all participants. We used a Nautilus T628 treadmill. We adapted the treadmill settings of the study of Morris et al. [33] by adjusting it to a secure and comfortable walking speed when immersed in the virtual environment. Specifically, we reduced the walking pace to 3km/h, kept the 1% incline, and reduced the walking time to two minutes per walking phase.

5 Results

We used mixed-ANOVAs for most analyses using virtual shoe pair as within factor and the subject's gender as between factor. If sphericity of the data could not be assumed after a Mauchly test, the Greenhouse-Geisser correction of degrees of freedom is reported.

In some analyses, homogeneity of variances cannot be assumed for all variables indicated by Levene's tests. In this case, the results of the ANOVA cannot be interpreted. Instead, only the results of post hoc tests are interpreted, which are independent of the assumptions of the ANOVA [17].

For eta squared, we interpret threshold values as small (.01), medium (.06), and large effects (.14) [9].

5.1 Participants

We recruited undergraduate students enrolled at the University of Würzburg. We used an online participant recruitment system that rewards students with credits mandatory for obtaining their bachelor's degrees. Additionally, few people participated on a voluntary basis without reward. Due to technical issues, we had to exclude the data set of one of the 40 participants. Therefore, we collected and analyzed data from remaining 17 male and 22 female participants.

Table 1: Descriptive data of the manipulation check in format $M(SD)$.

	Formality		
	low	medium	high
Men	2.41(1.00)	3.24(0.66)	4.18(0.81)
Women	1.27(0.46)	2.05(0.49)	3.68(0.57)

The female subjects were on average 22.32 years old ($SD = 3.05$) and 166.23 cm tall ($SD = 7.36$). The male subjects were on average 22.65 years old ($SD = 3.59$) and 176.12 cm tall ($SD = 9.41$). Five participants were left-handed. Two subjects were high school students, all others undergraduate students. One person reported a slight red-green deficiency, but was able to distinguish the colors used in the Stroop test without difficulty. Regarding immersive media use, only seven participants had not experienced VR before.

5.2 Manipulation Check

The analysis shows a significant interaction of the virtual shoe pair and gender, $F(1.46, 53.87) = 3.52, p = .050, \eta^2 = 0.02$, as well as a main effect for the shoe pairs $F(1.46, 53.87) = 104.06, p < .001, \eta^2 = 0.52$ and a main effect for gender $F(1, 37) = 48.38, p < .001, \eta^2 = 0.16$.

Neither sphericity of the data nor homogeneity of variances can be assumed for all formality level of shoes.

Bonferroni corrected post-hoc tests show that the outfit formality for both genders differ significantly between shoe pairs, $p <= .003$. Male subjects rated their outfits as more formal than female subjects, $t(37) = 6.96, p < .001$. Table 1 lists the descriptive data.

5.3 Gait Pattern

Our analyses revealed significant main effects for the factor *shoes* and *gender* displayed in Table 3 left and center. However, we found no interaction between the two factors displayed in Table 3 right.

Shoes The analysis shows significant main effects for the factor shoes for stride length, knee flexion at heel strike, and hip flexion at toe off. Post hoc test indicate the stride length to be significantly smaller with the most formal than with the medium ($t(37) = 3.25, p = .007$) and least formal shoes ($t(37) = 2.74, p = .028$).

Knee flexion at heel strike for the right leg differs significantly between the shoe pairs. Post hoc tests did not show significant differences though. For the left leg, the results of the ANOVA cannot be interpreted because of missing assumptions. Post hoc tests show significantly higher knee flexion at heel strike with the most formal than with the medium $t(37) = -2.58, p = .042$ and least formal shoes ($t(37) = -2.84, p = .022$).

Post hoc tests show significantly higher hip flexion at toe-off for the most formal than with the medium formal shoes $t(37) = -2.94, p = .017$ for the right leg. No significant results can be found for the left leg, $p > .055$.

Gender Significant differences were found for the factor gender. Stride length ($t(37) = -5.63, p < .001$) and pelvic tilt ($t(37) = -5.13, p < .001$) was significantly higher for female participants.

Knee flexion at toe off was lower for female participants for the right ($t(37) = 2.60, p = .013$) and left leg ($t(37) = 2.13, p = .040$). In addition, knee flexion at toe off ($t(37) = -2.46, p = .018$) and max knee flexion at stance ($t(37) = -2.05, p = .047$) was significantly higher for women for the left leg

Hip flexion at heel strike (right leg: $t(37) = 5.71, p < .001$, left leg: $t(37) = 5.50, p < .001$) and at toe off (right leg: $t(37) = 6.01, p < .001$, left leg: $t(37) = 6.52, p < .001$) was significantly lower for women. The maximum hip flexion at stance (right leg: $t(37) = 6.58, p < .001$, left leg: $t(37) = 3.57, p = .001$) and at swing (right leg: $t(37) = 5.29, p < .001$, left leg: $t(37) = 4.64, p < .001$) was lower for women, too.

Table 2: Descriptive data of the gait analysis in format $M(SD)$.

	Formality		
	low	medium	high
Male Subjects			
Stride Duration (in sec)	1.30 (0.12)	1.31 (0.10)	1.29 (0.11)
Stride Length (in m)	0.74 (0.12)	0.74 (0.14)	0.69 (0.11)
Pelvic Tilt	3.92 (1.09)	4.25 (1.44)	3.85 (1.29)
Pelvic Rotation	7.05 (2.50)	7.03 (2.45)	6.92 (2.33)
Shoulder Rotation	9.42 (4.23)	9.03 (2.64)	9.19 (3.09)
right:			
Knee Flex. Heel Strike	12.67 (5.68)	11.68 (6.76)	13.55 (6.44)
Knee Flex. Toe-off	30.56(18.87)	34.40(18.35)	32.01(15.96)
Max Knee Flex. Stance	32.61(11.64)	35.13(11.63)	32.89(10.94)
Max Knee Flex. Swing	62.30 (7.19)	62.72 (6.11)	62.45 (5.99)
Hip Flex. Heel Strike	40.49 (4.09)	40.00 (4.18)	40.32 (4.51)
Hip Flex. Toe-off	27.69 (8.73)	25.18 (7.17)	28.28 (6.49)
Max Hip Flex. Stance	40.74 (4.15)	39.89 (4.52)	40.65 (4.48)
Max Hip Flex. Swing	42.42 (4.85)	41.79 (5.07)	41.97 (4.54)
left:			
Knee Flex. Heel Strike	17.57 (8.84)	17.90(10.72)	20.07 (9.08)
Knee Flex. Toe-off	25.69(15.19)	25.87(19.02)	24.24(18.88)
Max Knee Flex. Stance	31.53(12.15)	32.53(11.15)	32.60 (9.11)
Max Knee Flex. Swing	61.60(10.62)	62.60 (7.88)	61.23(11.36)
Hip Flex. Heel Strike	38.82 (3.61)	38.25 (3.41)	38.21 (3.20)
Hip Flex. Toe-off	32.29 (6.74)	31.44 (7.45)	32.51 (5.48)
Max Hip Flex. Stance	36.33 (9.22)	37.40 (5.63)	37.85 (4.45)
Max Hip Flex. Swing	39.73 (3.63)	39.29 (3.57)	39.15 (3.09)
Female Subjects			
Stride Duration (in sec)	1.28 (0.09)	1.23 (0.11)	1.25 (0.11)
Stride Length (in m)	0.94 (0.09)	0.92 (0.12)	0.89 (0.13)
Pelvic Tilt	7.08 (1.99)	6.74 (2.18)	6.94 (2.41)
Pelvic Rotation	8.63 (3.46)	7.77 (2.90)	8.22 (3.57)
Shoulder Rotation	7.79 (3.19)	7.91 (3.83)	7.16 (2.93)
right:			
Knee Flex. Heel Strike	6.43 (6.26)	8.16 (5.36)	9.38 (6.15)
Knee Flex. Toe-off	34.04(15.74)	35.19(17.66)	35.20(17.49)
Max Knee Flex. Stance	34.42(15.08)	36.33(15.81)	36.55(15.29)
Max Knee Flex. Swing	65.24 (5.32)	63.40 (7.52)	62.94 (8.63)
Hip Flex. Heel Strike	32.50 (3.93)	32.69 (3.86)	33.28 (4.14)
Hip Flex. Toe-off	16.47 (6.10)	15.51 (4.71)	17.41 (5.49)
Max Hip Flex. Stance	31.81 (3.61)	32.56 (4.11)	32.08 (4.44)
Max Hip Flex. Swing	35.04 (3.92)	34.52 (3.89)	35.04 (3.79)
left:			
Knee Flex. Heel Strike	12.76 (5.82)	12.75 (7.19)	14.90 (6.28)
Knee Flex. Toe-off	36.89(14.48)	40.25(16.22)	33.17(16.94)
Max Knee Flex. Stance	39.38(11.65)	41.94(13.03)	36.26(14.44)
Max Knee Flex. Swing	63.32 (5.82)	64.10 (5.15)	63.36 (5.32)
Hip Flex. Heel Strike	31.77 (4.13)	31.66 (4.16)	32.17 (3.95)
Hip Flex. Toe-off	21.28 (5.67)	19.82 (4.31)	22.21 (6.55)
Max Hip Flex. Stance	31.42 (4.35)	31.26 (4.21)	31.88 (4.06)
Max Hip Flex. Swing	33.51 (4.30)	33.87 (4.05)	33.94 (4.11)

Angle measurements are given in degrees.

5.4 Cognitive Performance

The Stroop response time measurements contain outliers that are in the low hundredths of a second range. When conducting the experimental trials, we observed that occasionally when a button was pressed to answer a Stroop item, another button was additionally accidentally touched due to twisted hand postures, causing the next item to be also answered. These incorrect responses can explain the very low response times in the raw data. To exclude these outliers from the analysis, responses with a response time below the 1% percentile of all data points, i.e., less than 0.090 seconds, were removed.

Table 3: Gait behavior was evaluated with mixed ANOVA. The main and interaction effects of the analysis are reported. The degrees of freedom were corrected according to Greenhouse-Geisser.

	shoe				gender			shoe*gender			
	df_1, df_2	F	p	η^2	F	p	η^2	df_1, df_2	F	p	η^2
Stride Duration	1.97, 72.94	1.37	.261	0.01	2.23	.143	0.04	1.97, 72.94	2.29	.109	0.01
Stride Length †	1.61, 59.50	5.30	.012*	0.02	31.68	<.001*	0.40	1.61, 59.50	0.13	.835	0.00
Pelvic Tilt ‡	1.90, 70.48	0.25	.767	0.00	26.34	<.001*	0.39	1.90, 70.48	2.37	.103	0.00
Pelvic Rotation †	1.72, 63.48	0.97	.371	0.00	1.86	.180	0.04	1.72, 63.48	0.88	.405	0.00
Shoulder Rotation	1.78, 65.99	0.72	.473	0.00	2.55	.119	0.05	1.78, 65.99	0.77	.452	0.00
right:											
Knee Flexion Heel Strike	1.94, 71.78	4.01	.023*	0.02	6.75	.013*	0.13	1.94, 71.78	1.96	.150	0.01
Knee Flexion Toe-off †	1.71, 63.18	0.62	.517	0.00	0.25	.619	0.01	1.71, 63.18	0.22	.771	0.00
Max Knee Flexion Stance †	1.58, 58.44	0.65	.490	0.00	0.33	.568	0.01	1.58, 58.44	0.22	.753	0.00
Max Knee Flexion Swing †	1.65, 61.09	1.17	.309	0.00	0.43	.515	0.01	1.65, 61.09	1.81	.178	0.01
Hip Flexion Heel Strike †	1.68, 62.25	2.49	.100	0.00	32.62	<.001*	0.46	1.68, 62.25	2.82	.076	0.00
Hip Flexion Toe-off ‡	1.88, 69.42	3.57	.036*	0.02	36.17	<.001*	0.40	1.88, 69.42	0.36	.686	0.00
Max Hip Flexion Stance †	1.29, 47.61	0.05	.885	0.00	43.27	<.001*	0.50	1.29, 47.61	1.78	.188	0.00
Max Hip Flexion Swing †	1.47, 54.57	2.63	.096	0.00	27.98	<.001*	0.42	1.47, 54.57	0.44	.585	0.00
left:											
Knee Flexion Heel Strike ‡	1.93, 71.49	4.45	.016*	0.02	4.53	.040*	0.09	1.93, 71.49	0.03	.969	0.00
Knee Flexion Toe-off	1.92, 70.98	1.72	.188	0.01	6.08	.018*	0.11	1.92, 70.98	0.67	.510	0.00
Max Knee Flexion Stance ‡	1.86, 68.87	1.37	.261	0.01	4.21	.047*	0.08	1.86, 68.87	1.50	.231	0.01
Max Knee Flexion Swing	1.87, 69.37	0.80	.445	0.00	0.61	.441	0.01	1.87, 69.37	0.06	.928	0.00
Hip Flexion Heel Strike	2.00, 73.82	0.92	.404	0.00	30.23	<.001*	0.43	2.00, 73.82	1.98	.145	0.00
Hip Flexion Toe-off ‡	1.79, 66.32	2.11	.135	0.01	42.49	<.001*	0.46	1.79, 66.32	0.29	.723	0.00
Max Hip Flexion Stance †‡	1.51, 55.72	1.12	.318	0.00	12.74	.001*	0.22	1.51, 55.72	0.51	.551	0.00
Max Hip Flexion Swing	1.84, 67.92	0.04	.954	0.00	21.52	<.001*	0.35	1.84, 67.92	2.14	.129	0.00

applies to all calculations on the main effect gender: $df_1 = 1, df_2 = 37$
* indicates significant results with $p < .05$
† indicates a violation of the sphericity assumption
‡ indicates a violation of the homogenity of variances assumption

Table 4: Descriptive data on the percentage of correctly answered items and the required response time for items in seconds in the Stroop test in format $M(SD)$.

		Formality		
Items		low	medium	high
Correct Items (%)				
Congruent	men	0.97(0.04)	0.96(0.04)	0.95(0.06)
	women	0.95(0.07)	0.94(0.09)	0.97(0.05)
Incongruent	men	0.96(0.04)	0.96(0.05)	0.93(0.07)
	women	0.95(0.07)	0.94(0.08)	0.94(0.09)
Response Time (sec)				
Congruent	men	1.12(0.35)	1.11(0.46)	1.03(0.29)
	women	1.09(0.22)	1.08(0.20)	1.09(0.20)
Incongruent	men	1.15(0.42)	1.16(0.50)	1.02(0.29)
	women	1.11(0.17)	1.08(0.18)	1.07(0.17)

For the analysis, mixed ANOVAs with the additional within factor congruency of the Stroop items were computed. Descriptive data is documented in Table 4. The statistical analyses show a significant main effect of the factor congruency (Table 5). The sphericity of the data can be assumed. The homogenity of the variances cannot be assumed for variables of time measurement ($p = .021$) and of answer correctness ($p = .026$). Post-hoc tests show that congruent items were answered correctly significantly more frequently than incongruent items $t(38) = 2.09, p = .044$.

5.5 Simulator Sickness

We computed mixed ANOVAs with the within factor of measurement time (pre or post experiment) and the between factor gender. Homogeneity of variances can be assumed, $p > .794$. The total score of the simulator sickness increased significantly between the measurements before (men: $M = 14.52, SD = 14.60$, women: $M = 15.47, SD = 13.47$) and after the experiment (men: $M = 22.00, SD = 21.36$, women: $M = 23.80, SD = 21.17$), as indicated by the significant main effect, $F(1,37) = 9.76, p = .003, \eta^2 = 0.05$. There was no

Table 5: The Stroop test was analyzed using mixed-ANOVA with the within factors virtual shoe pair and congruency of items and the between factor gender. The main and interaction effects of the analysis are reported.

Effect	df_1, df_2	F	p	η^2
Correct Items (%)				
Shoe	2, 74	1.24	.296	0.01
Shoe*gender	2, 74	2.61	.080	0.02
Congruency	1, 37	4.37	.044*	0.01
Congruency*gender	1, 37	0.03	.854	0.00
Shoe*congruency	2, 74	1.47	.237	0.01
Shoe*congruency*gender	2, 74	0.21	.813	0.00
Gender	1, 37	0.26	.614	0.00
Response Time (sec)				
Shoe	2, 74	1.79	.175	0.01
Shoe*gender	2, 74	1.49	.233	0.01
Congruency	1, 37	0.91	.347	0.00
Congruency*gender	1, 37	1.01	.322	0.00
Shoe*congruency	2, 74	1.48	.233	0.00
Shoe*congruency*gender	2, 74	0.31	.734	0.00
Gender	1, 37	0.02	.895	0.00

* indicates significant results with $p < .05$.

significant main effect of gender ($F(1,37) = 0.07, p = .794$), nor a significant interaction of the factors ($F(1,37) = 0.03, p = .868$).

5.6 Qualitative Measures

In terms of comfort, ten subjects felt no difference between the shoes. Only two of the remaining 29 felt that the most formal shoes were more comfortable and justified this with the harmony of the avatar's look. Ten felt most comfortable wearing the bathing shoes, but many of them could not justify this feeling. Three justified the comfort with the memory of real bathing shoes, and two mentioned that it fits the season in the application best, as a Mediterranean harbor was visible through a window in the virtual shoe store. Most felt comfortable wearing the medium formal sneakers. Eight out of 17 people justified this by remembering the feeling of wearing sneakers in real life. Four felt a greater sense of safety in these shoes and justified their being comfortable. One subject justified their feeling by saying that they could walk best in this pair of shoes.

6 Discussion

We administered the SSQ to rule out that potential changes in gait and cognitive performance are not caused by an effect of cybersickness. In addition to a significant increase after the VR experiment, our measurements already indicate strong symptoms before the experiment. First, the experiment was conducted in summer. On some days, the outdoor temperature was above 30°C. Inside the laboratory, the temperature was also higher than average because there was no air conditioning. The tight full-body suits of the motion capture system might have additionally contributed to the fact that the subjects in VR felt even hotter. Since higher temperatures can evoke symptoms such as sweating, difficulties with concentration, or dizziness, the initial high ratings may be attributed to the weather. On the other hand, the measurements may also be due to the fact that people generally report a baseline value higher than 0 in SSQ, even if they are healthy [7]. Since the SSQ baseline was larger than the value of 0 suggested by Kennedy et al. [21], we consider only the increase in simulator sickness instead of the absolute value. The largest increase in simulator sickness was found in the disorientation subscale, with a mean of 10.75 scale points. According to Stanney et al. [53], only values above 20 define a bad simulator. Hence, we can assume that the results of this study were not strongly or if at all affected by the increase in simulator sickness.

6.1 Walking Behavior Adaptation

The gait when wearing the most formal shoe pair differed significantly from the two other shoe pairs at some measurement points. With the most formal shoes, the subjects took smaller steps and had higher knee flexion at heel strike and hip flexion at toe-off (on the right side) than with the other shoe pairs. We further found small effect sizes for stride duration, stride length, right as well as left knee flexion at heel strike, right as well as left hip flexion at toe-off, left knee flexion at toe-off, and left maximum knee flexion at stance. Even though all pairs of shoes differ significantly with a small effect size in their formality according to the manipulation check, the most formal shoes seem to have the greatest influence on gait. One possible reason for the differences could be that the subjects felt less relaxed and more professional in the most formal shoes than with the other two pairs, which are worn more often during leisure time. The subjects may have been more relaxed in the leisure shoes and therefore tended to take larger steps, among other things. Thus, our results indicate that virtual attire can evoke similar changes in self-perception as real workplace attire [2, 40]. A different explanation could be an expected influence of the physical constraints of the different types of shoes tested on the gait pattern of the participants. The participants produced perceptual illusions based on the visual appearance of the virtual shoes by experiencing intermodal integrations [5] and accounted for the expected impact of the formal and typically more stiff dress shoes on their natural gait.

We found differences with at least small effect sizes for every factor in gait between women and men. We found medium effect sizes for right as well as left knee flexion at heel strike, left knee flexion at toe-off, and left maximum knee flexion at stance. Finally, we found strong effect sizes for stride length, pelvic tilt, right as well as left hip flexion at heel strike and toe-off, and right as well as left maximum hip flexion at stance and swing. These strong differences are unsurprising, as body type, ratio of body part lengths, and height differ between men and women, which affects the mechanics of gait [44]. We did not find interaction effects of shoes and gender in the gait analysis. We, however, found small effect sizes for stride duration, right knee flexion at heel strike, right maximum knee flexion at swing, and left maximum knee flexion at stance.

29 of the 39 participants reported a difference in the comfort of the virtual shoes in our qualitative questionnaire. Five of them implied that they could walk better or more safely in some pairs of shoes than in others. Since only two people found the most formal shoes the most comfortable, it can be assumed that these tended to be the most uncomfortable shoes tested. These qualitative data, along with the gait analysis, suggest a high level of acceptance of the virtual shoes. It is also possible that the assumed lack of comfort in the most formal shoes can explain the differences in gait, where the most formal pair always differed from the other pairs of shoes.

Taken together, the results show that the initial priming with the individual pairs of shoes caused a permanent adaptation of the participants' mental model of the VR simulation. Throughout the remainder of the experimental trail, this mental model influenced the experiences of the participants, thus letting them feel and react to the assumed physical constraints of the different pairs of shoes. As we disabled the virtual mirrors, our results suggest that the mental model is persistent and requires no permanent reminder. Hence, we can assume that the participants completed the Stroop task under the impression of wearing the respective pair of shoes for the experimental trail. However, despite having found significant differences between the tested virtual shoes, we must **reject H1** as conjunction testing requires all constituent hypotheses to be accepted.

6.2 Cognitive Performance

Moreover, in this study, we also investigated whether the formality of the virtual shoes affects the cognitive performance of the wearer, since formal clothes can have influence on cognitive processes [52]. In the Stroop test, congruent items were answered correctly significantly more often than incongruent items, showing that the Stroop effect can be demonstrated by the test. No differences were found for response duration, which was also the case in the study by Adam and Galinsky [1]. In addition, no significant effects could be measured between pairs of shoes or the gender of the participants. However, we observed small effect sizes for the shoe factor for correct items and the response time. Also, we observed small effect sizes for the interaction of shoe and gender for correct items and response time. Men had more incorrect answers when wearing the most formal shoes compared to the other two shoe types. In contrast, women scored better in congruent items when they wore the most formal shoes. Men and women had a lower response time when wearing the most formal shoes. This result is notable as it suggests an effect of the type of shoe with respect to selective attention. The compiled mental model and the potential increase in felt professionalism might have affected and improved their selective attention. This supports the theory of an effect of Enclothed-Cognition evoked by the Proteus Effect. The avatars' clothing varied in formality with the pairs of shoes used, indicating that the manipulation of formality worked fundamentally well in the experiment. Although we found small effect sizes, the differences between the conditions were not great enough to reach significance. Hence, we need to **reject H2**.

7 Limitations

A limitation of our study is the demographic uniformity of our sample. We only recruited young university students with a strong affinity for the use of interactive media and VR. While this enabled us to approach an investigation of the effects of using different kinds of virtual shoes for avatars, it reduces the overall generalizability of our findings. In addition, we only gauged the potential influence of gender differences on the perception and effects of wearing different types of virtual shoes. To further advance this research direction, it is important to focus on additional variables, like felt attractiveness and competence, and a wider spectrum of gender identities. Moreover, we only focused selective attention and cognitive flexibility using the Stroop task to carefully approach the effects of virtual shoes without exhausting the participants. It is important to continue this research avenue to investigate potential effects on other aspects of cognitive performance. Lastly, our qualitative measures consisted of a single item only. While it provided insights into the general experience of walking in different virtual shoes, it lacks an in-depth assessment of the perception, experiences, feelings, self-esteem, and expectations of the participants concerning virtual shoes and their effects. A future experiment shall put a strong focus on the assessment of subjective experiences to gain a comprehensive understanding.

The implementation of the Stroop test in the virtual shoe store showed issues during execution. Twisted hand positions occasionally caused several buttons to be pressed at once, skipping the next item. As a result, not every subject was able to consciously process exactly 50 items per condition. In addition, outliers arose in the data, where the most extreme values were removed for evaluation.

In the Stroop test, it could happen that the same items were displayed directly one after the other. Since there was no fading or pauses between the display of the items, at such points the subjects may have been uncertain whether their input of the answer was possibly incorrect or did not work. This could have resulted in incorrect or delayed responses. Since it is not apparent from the log of responses whether the same items were displayed directly one after the other, such outliers could not be ruled out.

In the original Stroop test, the different font colors of words are read out [29]. In our version, buttons of the same color are pressed to submit an answer. This change may have oversimplified the Stroop test, since only the font color had to be matched with the colors of the buttons, where in the original a free answer was given and so more focus was on the word.

For further use of Stroop tests in VR, it is therefore recommended to revise the implementation of the test and align it with the original. For example, the *True Color* game of the memory training app Peak can serve as a model for an improved version [41]. In this game, the Stroop item is displayed on a card. Above it is a color word written in black font color on another card. At the bottom of the screen are two buttons that stand for *yes* and *no*. The user compares the font color of the item with the color word above it and logs in using the buttons to see if the two match. Thus, there is more focus on the actual color word, making it closer to the original Stroop test than our version. Also, when implementing Peak's version in VR, we can be careful to place the two buttons with enough distance in between so that both buttons cannot be pressed at once unintentionally.

8 Conclusion

Our research investigated the effects of virtual shoes on cognitive abilities and human gait during a VR walking task. During our user study, participants tried on three pairs of virtual shoes differing in formality. The participants walked for two minutes in each pair of shoes after a familiarization phase. Subsequently, they completed a Stroop task to assess their selective attention.

Although the study results did not show any significant differences between the virtual shoes tested, the small effect sizes suggest an influence of shoe formality on selective attention. Our study thus suggests that Enclothed-Cognition could also be evoked in VR by small factors such as shoes. Additionally, we found significant differences in the gait and the overall perception of the shoes. This indicates that virtual shoes are not only accepted as one's real shoes, but also influence movement behavior. It suggests that the Proteus Effect goes beyond behavioral changes on a stereotypical level. These findings are notable.

Future research needs to continue the investigation of the effects of wearing virtual shoes. Being part of one's clothing and simultaneously eliciting certain physical constraints based on their structure turns them into an ideal aspect to investigate whether there is a second level of behavioral changes beyond stereotypical conformity. In addition, it is important to repeat our experiment using a wider as well as larger demographic group and administering additional cognitive tasks to gain a more in-depth understanding of the perception and effects of wearing different types of virtual shoes. Moreover, the continuation of this research should conduct a post-experiment interview to gain more subjective feedback about the perception, experiences, and expectations of the participants.

Acknowledgements

This research has been funded by the Bavarian State Ministry For Digital Affairs in the project XR Hub (project number A5-3822-2-16).

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