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Isabel Mayer
University of Bern
Sebastian Stefani
Michael Rihs
michael.rihs@unilu.ch

UniDistance Suisse
Matthias Ertl
University of Lucerne

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Bodily Self-Perception During Vestibular Galvanic Stimulation in Virtual Reality: A Replication and Extension of Karnath et al. (2019)

Isabel F. Mayer[1], **Sebastian Stefani**[0], **Michael Rihs**[1,2,3*+], **and Matthias Ertl**[1,3,4+]

[0]Independent Researcher
[1]Institute of Psychology, University of Bern, Switzerland, Bern, 3018, Switzerland
[2]Faculty for Psychology, UniDistance Suisse, Brig, Switzerland
[3]Faculty of Behavioural Sciences and Psychology, University of Lucerne, Switzerland
[4]Clinic for Neurology and Neurorehabilitation, Luzerner Kantonsspital, University teaching and research hospital, and University of Lucerne
[*]michael.rihs@unilu.ch
[+]these authors contributed equally to this work

ABSTRACT

One of the less explored functions of the human vestibular system is its contribution to bodily self-perception. The continuous integration of vestibular and other sensory information is assumed to build the foundation for perceiving one's body size and shape. The present study aims to replicate and extend findings from Karnath et al. (2019)[1] regarding the modification of bodily self-perception through bilateral galvanic vestibular stimulation (GVS). Twenty healthy participants took part in a virtual reality (VR) setup with a semi-personalized avatar (i.e., self-adjusted arm length) during GVS to assess the effects of DC- and AC-GVS on bodily self-percepton. A repeated measures ANOVA revealed that neither GVS type or intensity had a significant effect on perceived arm size, successfully replicating the findings from Karnath et al. (2019)[1]. However, we could not replicate the effect of body side found in the original study. The findings suggest that GVS does not modulate perceived arm size.

Introduction

Successful navigation and interaction with our immediate world require, at the very least, an implicit understanding of the dimensions of our body and extremities. The visuo-spatial and proprioceptive processing of bodily dimensions is fundamental in creating an inner representation of the body[2], where the vestibular system is critical in the multisensory integration required for self-representation[3]. The vestibular system, consisting of the semicircular canals and otolith organs, has gathered attention in neuroscience and cognitive psychology due to its crucial role in detecting head movements and spatial orientation relative to gravity[4,5]. Furthermore, research suggests that the vestibular system is also involved in cognitive processes such as navigation and spatial memory[6–8]. These vestibular functions require a robust and flexible inner representation of the body and its orientation in the world (e.g., body position relative to the gravitational field of the earth). This inner representation requires accurate bodily self-perception and proprioceptive information processing, resulting in a dynamic internal model that is continuously adjusted according to internal and external sensory signals[9–11]. Several studies have identified the impact of the vestibular system on self-perception where individuals with chronic vestibular disorders report distorted body image perception[12], whereas vestibular stimulation in amputees can elicit the perception of a previously absent phantom limb, or reduce pain in an existing one[13]. Further, other studies suggest that the vestibular system influences bodily self-perception[14–16], however, did not provide a detailed mechanism for these observations. Contrastingly, other studies have outlined the lack of vestibular input on bodily self-perception[1,17]. In light of previous research, the present study aims to expand on the role of the vestibular system in bodily self-perception[1] during artifical vestibular stimulation using biometric avatars in virtual reality.

Caloric vestibular stimulation (CVS) and galvanic vestibular stimulation (GVS)[5] are two tools used to assess the function of the vestibular system and artificially stimulate it in situations where actual motion is not possible (e.g. MRI scanners). CVS involves irrigating the ear with cold or hot water, which primarily stimulates the semicircular canals responsible for detecting head rotations[18,19]. GVS involves transcutaneous electrical stimulation with the electrodes placed over the mastoids behind the ears[20]. It allows for a temporal precise and adaptable stimulations that can be adjusted to specific sensory thresholds[21]. GVS enables continuous vestibular modulation with less painful cutaneous sensations, therefore allowing for slightly higher

amplitude adjustments compared to CVS[20]. It can be applied at subthreshold or suprathreshold intensities to perturb or improve participant performance in balance and perception tasks[22,23], with the placement of the electrodes influencing the current distributions[24].

CVS and GVS have been used to manipulate vestibular input in the context of bodily self-perception research. For example, CVS has been used to modulate somatosensory sensitivity and thereby influence the perceived length and width of particular body segments such as the hands and thighs[14–16]. Meanwhile, the impact of GVS on perceived body metrics remains less understood[25] and results are less consistent. For instance, Ferrè et al. (2013) found that GVS did not impact the perceived length and width of the hand, while Lopez et al. (2010) observed an increase in illusory ownership of the left hand with GVS during the "rubber hand illusion". One explanation for the heterogeneity of the results are the variations in protocols, including differences in stimulus character and stimulation type used by the various GVS studies[26]. Additionally, the stimulus intensity and the applied waveform (direct current DC-GVS or alternating current AC-GVS) have a significant impact on the perception of the stimuli[20].

Karnath and colleagues[1] subsequently observed that neither CVS nor DC-GVS significantly changed the perceived length of the arms and legs in a VR setting. These results suggest that DC-GVS does not modulate bodily self-perception via the vestibular system when applied at subthreshold intensities. Interestingly, they found an effect of body side regardless of stimulation, suggesting an asymmetry in body perception in healthy participants, with extremities on the right body side being slightly more overestimated than those on the left. Although this finding aligns with previous research showing that vestibular stimulation can induce neglect-like phenomena and a tonic bias in head orientation even in neurologically healthy individuals[27,28], the observed effect is unexpected, as it occurred regardless of DC-GVS application. It remains unknown whether these findings are attributed to the stimulation modality or the subthreshold amplitudes used. Further, no study has attempted these experiments using suprathreshold AC-GVS, which more closely mimics natural vestibular dynamics by continous stimulation, rather than short on- and offset effects[20].

This study aims to replicate and extend the findings from Karnath et al. (2019) on the effects of GVS on bodily self-perception, particularly its influence on perceived arm length. This study also aims to identify the impact of AC-GVS on bodily self-perception in addition to DC-GVS which was used in the original study[1]. The aim was to explore the influence of current directionality on the modulation of body perception, as well as the bodily asymmetry observed in the original study. We extend on the original protocol, by adding a second high-intensity DC-GVS condition, and by applying AC-GVS in a low and high intensity condition. These new conditions allow us to rule out that the absence of an effect in the Karnath study[1] was caused by subthreshold stimulus intensities, or caused by habituation to the tonic direct current stimulation. We assume that higher intensities in combination with prolonged perception as caused by AC-GVS is sufficient to observe an effect of GVS on body self-perception[29]. We further predicted that the effect of body side found in the original paper would be replicated and more pronounced in the DC-GVS conditions than in the AC-GVS conditions, due to the asymmetrical nature of this configuration's activation pattern. With this replication, we aim to determine the role of stimulation type and intensity in the modification of perceived body length, thereby contributing to the understanding of the vestibular system's role in shaping bodily self-representation.

1 Methods

Statement of Transparency

The present study was pre-registered on OSF prior to data collection[1]. In our preregistration, we planned a 3x2 ANOVA with stimulation type (no stimulation, DC, AC) and body side (left, right) as within subject factors. Post-registration we decided to add a high intensity stimulation as an additional condition. We will report both our registered analyses, and an extended analysis using a 5x2 ANOVA with 5 stimulation conditions (no stimulation, DC low, AC low, DC high, AC high). All research materials, data, and analyses are publicly available in the associated OSF repository[2]. We utilised the methodology of Karnath et al. (2019)[1] as a foundation for this study, however, several modifications were made to the original study design. Specifically, due to time limitations, we did not assess individual thresholds but used a constant current of 0.375 mA to replicate the originally applied average of 0.38 mA. The only variable manipulated was arm length, as in the original study arm length was significantly more overestimated by participants than the length of the legs. This suggests that the influence of the vestibular system is stronger for extremities of closer proximity. Alternatively, this might be explained by larger homuncular representation in the primary motor and sensory cortices. Contrary to Karnath et al.[1], we omitted the sham condition and shortened the breaks

[1] https://osf.io/2uc3p/?view_only=748603107b8944fdb134a8f79d8a2138
[2] https://osf.io/2zwck/?view_only=aba783a425c846acbfa99daaab7fcf03

between assessments from 15 to 5 minutes. Additionally, we added AC-GVS and high current conditions to achieve an identical session duration of 90 minutes. We used a reclining seat instead of a bed, leading to a larger body tilt (45° instead of 30°). We also used a more advanced VR headset (HTC Vive Pro 2 instead of Oculus Rift DK2), avatar (Makehuman instead of statistic models based on the CAESAR dataset;[30]) and a newer version of the Unity game engine (2022.3.2f1 instead of 4.6.3f1) due to equipment availability. The feedback questionnaire used by Karnath et al. (2019)[1] was translated into German and expanded with four questions used in a previous study[20].

Participants and Recruitment

Based on the parameters of the original study, we conducted an a priori power analysis for a repeated measures ANOVA using G*power[31]. The analysis suggested a minimal sample size of 20 participants to detect an effect with a medium effect size (f = 25), an alpha of 0.05, a power of 0.80, and a correlation of r = 0.65. In line with the estimated sample size, we recruited 20 undergraduate psychology students (mean age = 22.4+/- 1.5(SD); range 20-24) enrolled at the University of Bern, Switzerland between February and March 2024. Seventeen students identified as female (85 %) and three identified as male (15 %). The average height of the participants was 169.7 cm (SD = 8.19 cm) and the average arm length was 70.7 cm (SD = 3.66 cm). Additional five participants were recruited for piloting the experimental procedure. All participants voluntarily signed up through the University's online participant pool and received 1.5 credit points each for taking part in the study.

Inclusion criteria for participating in this study were: a) no history of vestibular problems, b) no history of hearing problems, c) right-handedness. The criterion of right-handedness was added in order to facilitate comparisons with the original study that had been conducted with 20 right-handed and two left-handed participants. Research suggests a right hemispheric dominance for vestibular information processing[29], and CVS has been shown to produce different activation patterns based on participant handedness[19]. The study has been reviewed and approved by the Ethics Committee of the Faculty of Human Sciences of the University of Bern (2020-04-00004). Methods were carried out in accordance with the relevant guidelines and regulations and in accordance with the Declaration of Helsinki.

Setup

The virtual avatar was displayed with SteamVR using the Unity game engine (3.2f1)[3], a motion-tracked head mounted display (HTC Vive Pro 2; 2,448 × 2,448 pixels per eye), and a desktop PC (using a NVIDIA GeForce GTX 1080 Ti graphics card and an Intel Core i7 processor). The same default avatar was used for all participants and was retrieved from Makehuman[4]. The scaling of body parts was created in Blender[5] using the Add-On Rigify[6]. Bipolar left anodal and right cathodal GVS was applied using a NeuroConn DC stimulator Plus (neuroCare Group GmbH, Munich, Germany). Two rubber electrodes (5x7 cm) inside sponges saturated with saline solution were fixed to the participants' mastoids using flexible rubber bands.

Procedure

Each participant signed an informed consent form upon arrival, and their body height and arm length (from the apex of the shoulder to the tip of the middle finger) were measured by the researcher. During the experiment, participants were in a reclined position with their upper body at a 45° angle, and arms on armrests by their side. Throughout each experimental condition, participants had a first-person view of their virtual avatar which corresponded to the body position of the original study in an empty environment (see Figure 1). The avatar's body size and arm length were adjusted to match each participant's measurements.

Participants had to adjust their virtual avatar's arm length to the length of their own arms. At the start of each trial, the virtual arm was presented either elongated or shortened by 20 %, 25 %, 30 %, 35 % and 40 % of the actual arm length, in randomized order. Participants then verbally instructed the examiner ("longer"/"shorter"), who used the keyboard to adjust arm length in steps of 2.5 % of the actual arm length until the participant was satisfied. There was no time restriction, and participants did not receive feedback on their accuracy. The non-target side of the virtual avatar's body was masked by a grey cover during the entire trial.

In total, 20 trials (10 times left arm, 10 times right arm) were presented for each stimulus condition. Participants started with the baseline assessment (no GVS) before repeating the task under the other four stimulation conditions (alternating (AC)/direct current (DC)-GVS at 0.375 mA and 1 mA). The order of stimulation conditions remained the same for all participants, and stimulation was applied continuously throughout the sessions that lasted between 5 and 15 minutes. A 5-minute break was administered between each stimulation session. In the DC-GVS condition, the anode was placed on the left, the cathode on

[3]https://unity.com/releases/editor/whats-new/6000.0.32#installs
[4]http://www.makehumancommunity.org/
[5]https://www.blender.org/
[6]https://developer.blender.org/docs/features/animation/rigify/

the right mastoid, referred to as L-GVS in research conventions[17]. In the AC-GVS condition, the polarity of the electrodes alternated sinusoidally between the left and right mastoids at a frequency of 0.25 Hz with this being one of the frequencies that led to the greatest response of head displacement in a study conducted by Latt et al.[32].

After each GVS condition, participants completed a questionnaire on perceived vertigo and sickness[1], as well as their perceived sensation of self-motion along the yaw, roll, and pitch axes[20]. Perceived vertigo was rated on a Likert Scale ranging from 0 to 10 (0 = no vertigo, 10 = very strong vertigo). At the end of the experiment, participants completed another questionnaire regarding their level of identification with the avatar and its body parts[1]. Participants rated the similarity of the avatar's body parts to their own on a 1-7 Likert scale (1 = not at all, 7 = very much). The original questionnaire as published in table 1 of the original study[1] was translated to German. The translated version of the questionnaire can be found in Appendix A.

Outcome Parameters

For all participants, the results of each of the 5x20 trials were summarized into a body perception index (BPI = (estimated size/actual size) x 100), indicating the deviation from the subjectively perceived arm length to the actual arm length. A BPI above 100 represents an overestimation, while a BPI below 100 represents an underestimation of one's own body. Mean BPIs were calculated for each condition and body side separately, yielding ten BPIs per participant.

Data Analysis

Preregistered Analysis

A 3x2 repeated measures ANOVA was performed on mean BPIs with stimulation condition (baseline, low DC-GVS, low AC-GVS) and body side (left, right) as within subject factors to replicate the findings by the original study[1]. The baseline assessment was conducted without any stimulation. Outliers were winsorized using an upper and lower threshold of ±2 standard deviations (SD). Six trial data points were adjusted to -2 SD, five of which were from the same participant, and no data values exceeded +2 SD. In total, two out of each of the five stimulation conditions were affected. To detect the impact of outlier data, the repeated measures ANOVA was calculated twice, with and without winsorization.

Extended Analysis

Because our study design included low and high intensities, we conducted an additional, exploratory analysis. A 5x2 repeated measures ANOVA was performed on mean BPIs with stimulation condition (baseline, low DC-GVS, low AC-GVS, high DC-GVS, high AC-GVS) and body side (left, right) as within subject factors. Again, outliers were winsorized to ±2 standard deviations (SD). Ten trial data points were adjusted to -2 SD, nine of which were from the same participant, while no data values exceeded +2 SD. In total, two out of each of the five stimulation conditions were affected. To detect the impact of outlier data, the repeated measures ANOVA was calculated twice, with and without winsorization.

An additional exploratory analysis was performed to compare the effects found in the original study and detect trends in our data, despite insignificant results of the main analysis. Wilcoxon signed-rank tests were conducted for pairwise comparisons, given that a Shapiro-Wilk test indicated a violation of the normality assumption. Paired t-test, as used in the original study, were performed post-hoc to compare outcomes. In addition, equivalence tests between each condition and body side were performed to test for an absence of effect. The complete R code and scripts used for the analysis are openly accessible on OSF[7].

Results

Preregistered Analysis

Throughout all conditions, participants tended to underestimate their arm length, as demonstrated by a mean BPI lower than 100. Descriptive statistics of the BPI across the different conditions are summarized in Table 1. The 3x2 repeated measures ANOVA revealed no significant main effect for stimulation (F(2, 114) = 1.97, p = 0.145; $\eta_p^2 = 0.03$, 95% CI [0.00, 1.00]), body side ($F(1,114) = 2.03e^{-03}, p = 0.964; \eta_p^2 = 1.78e^{-05}$, 95% CI [0.00, 1.00]), and no significant interaction effect (F(2, 114) = 0.03, p = 0.968; $\eta_p^2 = 5.69e^{-04}$, 95% CI [0.00, 1.00]). Equivalence tests for all comparisons between conditions were not significant (p-values ranging from 0.24 to 0.93), suggesting that there is insufficient evidence to confirm that the true difference lies within the smallest effect size of interest of 0.64, assuming a minimum increase in perceived arm length of 0.9 cm according to the original paper[1].

Extended Analysis

The 5x2 repeated measures ANOVA revealed no significant main effect for stimulation type ($F(4,190) = 1.495, p = 0.205; \eta_p^2 = 0.03$, 95 % CI [0.00, 1.00]) or body side (F(1, 190) = 2.10^{-05}, p = 0.996; $\eta_p^2 = 1.11e-07$, 95 % CI [0.00, 1.00]). The interaction

[7] https://doi.org/10.17605/OSF.IO/2ZWCK

of stimulation type and body side was also not significant ($F(4,190) = 0.02, p > 0.999; \eta_p^2 = 4.02e-04$, 95 % CI [0.00, 1.00]). The winsorization of outliers did not change these results. Figure 2 depicts the BPI across the conditions. Equivalence tests for the comparisons between conditions were not significant (DC low vs. DC high p = 0.43; AC low vs. AC high p = 0.57; DC low vs. AC low p = 0.4; DC high vs. AC high p = 0.53), suggesting that there is insufficient evidence to confirm that the true difference lies within the smallest effect size of interest of 0.64, assuming a minimum increase in perceived arm length of 0.9 cm according to the original paper[1].

Questionnaire Data

Participants rated the overall similarity of the avatar to themselves 3.65 on average (SD = 1.35). The similarity of the avatar's arms was rated 3.60 on average (SD = 1.39). Fourteen participants reported having the impression that the setup at least partially represented them in a virtual environment, six participants reported the opposite (results in Table 2). Ten participants reported that the avatar's hands or arms looked weird or uncanny to them, two reported the same for the avatar's legs or feet. Participant strategies to solve the task included using intuition (n = 6) and matching the distance of the avatar's hand to the thigh (n = 17).

Participants most reported feeling the stimulation as a tingling or pinching sensation beneath the electrodes. Ten participants reported feeling mild vertigo during or after the stimulation, with an average rating of M = 3.37. Vertigo was more likely to be reported in the AC-GVS (n = 14) compared to the DC-GVS condition (n = 5), and in the high current (n = 13) compared to the low current condition (n = 6). A Chi-Square test confirmed the significant relationship between condition and reported vertigo ($\chi^2(3,80) = 9.04, p = 0.029$). A McNemar's test for pairwise comparisons revealed a higher amount of reported vertigo in the AC high than in the DC low condition (McNemar's $\chi^2(1,80) = 6.13, p = 0.01$). No participant experienced vertigo in all conditions. Only one participant experienced sickness in three of the conditions.

Several participants perceived movement during the GVS stimulation, twelve of during the AC-GVS high condition, and five during the DC-GVS high condition. Only two participants perceived a movement during the DC-GVS low and four during the AC-GVS low condition. All participants reported feeling the movement along the roll-axis, one participant additionally reported also perceiving it along the pitch-axis. In 35 % of the cases participants felt a movement of their head, in 65 % of the cases they felt a movement of the entire body. The latter was most often reported during the AC-GVS high condition (80 %).

Discussion

In line with the findings of Karnath et al.[1], in our replication study identified that DC-GVS did not significantly influence participants perceived arm length when applied at 0.375 mA compared to baseline. Extending this result, we also found no significant main effect of stimulation type, indicating that neither DC-GVS nor AC-GVS applied at 0.375 or 1.0 mA significantly changed perceived arm length. These findings reiterate previous work suggesting that vestibular stimulation does not consistently modulate higher-order body representations. Despite the absence of significant differences, descriptive statistics suggest an increase in perceived armlength under GVS. This suggests that a potential effect of GVS on body perception might exist but is much smaller than previously suggested[15].

In contrast to earlier studies[1,15], where an overestimation of armlength was observed, our participants systematically underestimated the armlength. This discrepancy might be explained by slight differences in participant posture. For example, body posture was different between all three studies with participants lying on a bed[1], sitting on a chair[15], and seated in a chair with their heads cushioned in the current study. As such, participants in our study were potentially more elevated compared to those in Karnath et al. (2019)[1], which may have affected perceived proximity of limbs. However, head orientation was continuously monitored and animated using the inertial measurement unit (IMU) built into the VR goggles, accounting for changes in visual perspectives.

Interestingly, we could not reproduce the effect of body side found by Karnath et al.[1], where the overestimation of arm length was more pronounced on the right side. In our study, both the main effect of body side and the interaction of body side and stimulation type were not significant. Whereas the original study included both right- and left-handed participants (n = 20 vs. n = 2), we only included right-handed participants to control for lateralization asymmetry in vestibular regions[19], which did not seem to influence the results. However, while Karnath et al.[1] applied stimulation at individual threshold levels, vestibular thresholds were not assessed in the present study, and stimulation intensity therefore likely varied in its effective strength across participants, potentially obscuring lateralized effects.

In line with our expectations, participants feedback, by questionnaire, indicated that AC-GVS induced more frequent subjective vestibular sensations (i.e., perception of stimulation, movement, vertigo, and sickness) compared to DC-GVS. Furthermore, this effect was correlated with stimulus intensity, where higher stimulus intensity (1.0 mA) led to stronger

subjective vestibular sensation than the lower stimulus intensity (0.375 mA)(see Table 2). This aligns with previous research suggesting that AC-GVS at strong current intensities can produce conscious vestibular sensations[17,33,34].

The baseline deviation from the expected mean BPI of 100 in both studies suggests a susceptibility to postural mismatch errors in the protocol, which might not be ideal for reliably recreating head-to-body distances. Although we made sure to adjust each participants position with cushions, we cannot fully exclude the possibility of subjective mismatches with the avatar's position. Ratings on how the avatar's shape and proportions matched participants body were comparable with those reported previously[1] and other studies employing semi-individualized avatars[35]. We did not assess each participants sensory threshold but rather applied the the same stimulation intensity to all participants. Therefore, the applied stimulation might only have been suprathreshold to some participants but not to others. This should be considered when interpreting the results of the current study.

Results may also have been influenced by the reliance on comparative visual strategies reported by 85 % of our participants as compared to 29 % in Karnath et al. (2019)[1]. This reliance potentially overrides other somatosensory information, thereby minimizing the desired contribution of multisensory integration to task performance. Judgments of body part size operate at the somatorepresentational level, making them less sensitive to bottom-up somatosensory input and more susceptible to visual and cognitive influences[17]. This may indicate that the vestibular system, although potentially involved in tactile detection and localisation, does not directly impact our ability to interact with our immediate world in everyday life, as it is masked by higher-order multisensory and top-down information processing in healthy people. Its influence might be better explored and understood when stimulation is applied at even stronger rates, conflicting sensory input is minimized, or when assessing patients with sensory impairments. This is supported by the more frequent reports of vestibular sensations during high-intensity AC-GVS in the present study.

The question remains whether the vestibular system influences body self-perception and if so, how this effect unfolds. While some studies observed effects of vestibular stimulation on body self-perception, the underlying mechanisms remain unclear. Future resarch should aim at integrating pre-existing finding into a coeherent theory on how the vestibular system affects body self-perception. In doing so, future reserch should also expect smaller effects sizes and therefore aim at recruiting larger sample sizes as both our and Karnath et al. (2019)[1] did not find significant effect sizes by expecting the medium effect size as previously reported[15].

Conclusion

The present study replicated and extended research on galvanic vestibular stimulation (GVS) and bodily self-representation. In alignment with previous research, DC-GVS applied at 0.375 mA did not influence the perceived size of participants' arms. However, none of the stimulation conditions, neither DC-GVS nor AC-GVS, significantly altered perceived arm length at either stimulation intensity (0.375 mA or 1 mA), suggesting a context-dependency and interfering dominance of visual or top-down information processing. These findings highlight the need for more refined experimental designs minimizing conflicting sensory input, improved VR setups, and larger samples to better understand the distinct vestibular contribution to multisensory body representation.

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Author contributions statement

M.E. supervised the study as the professor of the seminar during which the study was conducted (**Supervision**). The replication study was conceptualized and designed by I.M. based on the original study (**Conceptualization, Methodology**). I.M. conducted data collection and performed the statistical analysis (**Investigation, Formal Analysis**). M.R. developed the VR program and supported the technical implementation (**Software, Resources**). I.M. drafted the manuscript (**Writing – Original Draft**). All authors critically reviewed and contributed to the finalization of the manuscript (**Writing – Review & Editing**). All authors approved the final manuscript.

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Additional information

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Table 1. Aggregated body perception indices (BPI; estimated arm length / actual arm length * 100) for each condition and body side. DC = direct current; AC = alternating current; low = 0.375 mA; high = 1 mA; SD = standard deviation.

	Total		Left		Right	
Condition	Mean	SD	Mean	SD	Mean	SD
Baseline	88.06	9.46	87.94	8.89	88.18	10.23
DC Low	91.83	9.72	91.71	10.17	91.96	9.53
AC Low	91.86	10.05	92.23	9.55	91.50	10.76
DC High	92.07	9.49	91.93	9.43	92.21	9.80
AC High	92.89	9.41	92.89	9.65	92.89	9.42

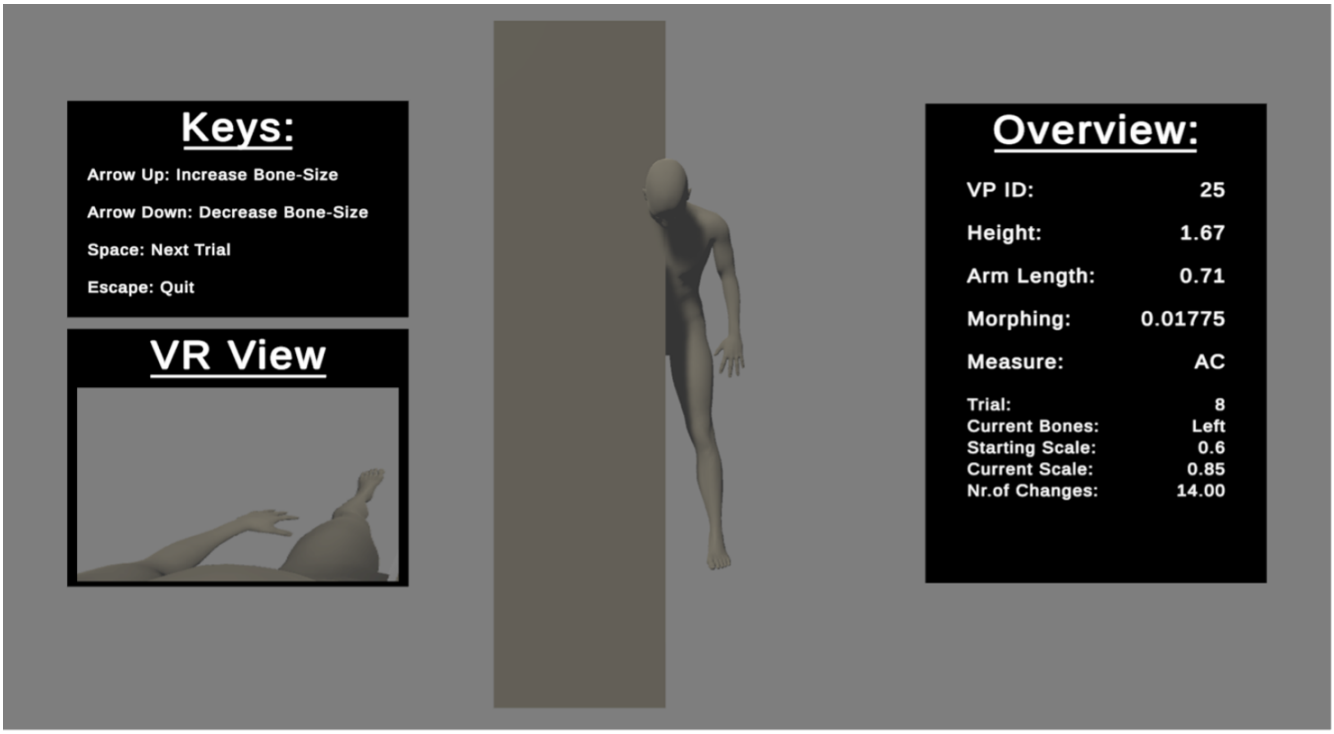


Figure 1. Biometric avatar used in the virtual reality setup. The window on the left-hand side presents the virtual avatar as perceived by the participant. The window on the right-hand side provides an overview of the parameters used.

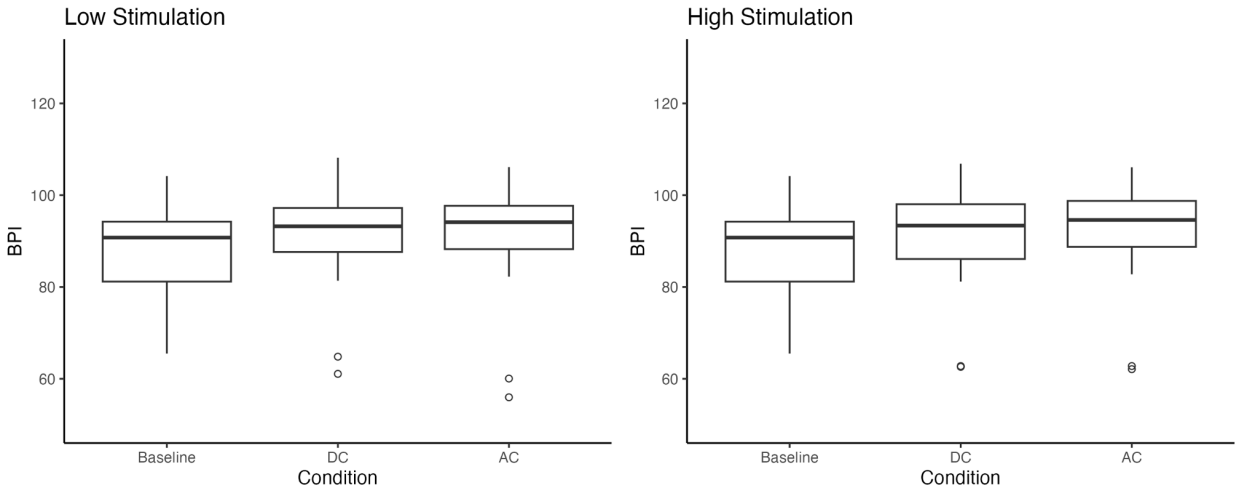


Figure 2. Boxplots depict the distribution of Body Perception Index (BPI) scores (estimated arm length / actual arm length * 100) across conditions of transcranial DC-GVS and AC-GVS at low (0.375 mA) and high (1 mA) intensities.

Table 2. Summary of selected feedback questionnaire responses regarding virtual reality and side effects of the stimulation. Complete questionnaire items are available in Appendix A and B.

Questions (n = Yes)				
Condition	Did you feel the stimulation? (n = Yes)	Did you perceive a movement? (n = Yes)	Did you feel vertigo? (n = Yes)	Did you feel sick? (n = Yes)
DC Low	14	2	1	0
AC Low	9	4	5	1
DC High	20	5	4	1
AC High	16	12	9	1

How similar to you was the person that you saw through the glasses? (1 = not at all, 7 = very much)		
	Mean	SD
Overall impression	3.65	1.35
Shape (e.g. proportions)	4.05	1.00
Appearance (like you or like a stranger?)	2.85	1.46
Arms	3.60	1.39
Torso	3.35	1.53

Questions	**Answers**
Did you have the impression that the setup represents you in a virtual environment?	No (6), Partly (8), Yes (6)
Which strategies did you use to solve the task?	Match to thigh (17), intuition (6)
Did any of the body parts look weird or even uncanny to you? If so, which?	Hands (8), None (7), Torso (3), Arms (2), Feet (1), Legs (1)