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Learning eco-friendly food choice using extended reality – an exploratory investigation

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Introduction: It has not yet been investigated whether virtual reality (VR) may be useful to support the learning of eco-friendly food choice by enabling human individuals to experience motivational behavior-environment associations that depending on the carbon footprint of their food choice affect them negatively or positively. It is, accordingly, an open question if the viewer-including environment of VR can serve for this purpose better than a viewer-excluding PC version of it. We have, therefore, started to investigate this potential utility of VR in an exploratory investigation on the level of lower secondary education.

Methods: For this purpose, we have developed both a VR and a PC version of a task involving the following experience: the problem that choosing environmentally harming food with a high carbon footprint is accompanied by climate-related environmental alterations that are affecting oneself negatively can be solved by replacing this food with eco-friendly food with a low carbon footprint, which is accompanied by a reversal of such environmental alterations that is affecting oneself positively. In a first experiment, we have asked experienced lower secondary school teachers to test both the VR and PC version of our task and to rate its usefulness to teach eco-friendly food choice. In a second experiment we have subsequently started to explore the learning curve of lower secondary school children accomplishing either the VR or the PC version of the task by measuring their times to solve the problem involved in the task three consecutive times.

Results: In the first experiment the teachers regarded the VR version of the task to be more useful for teaching eco-friendly food choices than its PC version. In accordance with this finding, in the second experiment the children were learning to solve the problem involved in the task more rapidly using its VR version than using its PC version.

Discussion: Hence, our findings converge in suggesting the following: experiencing motivational behavior-environment associations that depending on the carbon footprint of one's food choice affect oneself negatively or positively using the VR version of our task may serve better to support the learning of eco-friendly food choice than using its PC version.

KEYWORDS

learning, eco-friendly behavior, food choice, environmental changes, virtual reality, immersive education, metaverse

1 Introduction

The ecosystems of Earth are important for human wellbeing (Millennium Ecosystem Assessment, 2005). Climate-related changes in these ecosystems are, therefore, a threat and found to induce anxiety (Hickman et al., 2021). Such climate-related environmental changes are driven by greenhouse gas emissions linked to human action (Yue and Gao, 2018). Almost 30% of these emissions are caused by the production of food (Poore and Nemecek, 2018). Hence, eating more food with a low carbon footprint and less food with a high carbon footprint has the potential to reduce greenhouse gas emissions significantly. Such environmentally responsible, pro-environmental, or *eco-friendly* food choice requires that human agents relate themselves and their natural environment to each other accordingly (Davis et al., 2009). To adopt a food choice behavior that is eco-friendly human individuals must, therefore, learn that this behavior is part of an agent-environment (Kaufmann-Hayoz, 2006) or human-environment (Heft, 2001) relation. From the perspective of associative learning (Schneider and Sanguinetti, 2021) they may accomplish this by experiencing the following two motivational behavior-environment associations or contingencies in space and time: choosing environmentally harming food with a high carbon footprint is accompanied by climate-related environmental changes that are negatively affecting the person making the choice (Brügger et al., 2015), choosing eco-friendly food with a low carbon footprint is accompanied by a reversal of these environmental alterations that is positively affecting the person making the choice (Andreatta et al., 2012). Learning such behavior-environment associations may have the potential to establish within human individuals the motivation for eco-friendly food choice behavior. A promising opportunity to foster this kind of associative learning in a rather large part of society could be in lower secondary education (D-EDK, 2016).

One of the main goals of secondary education is to prepare learners for daily life. This goal may be achieved by anchoring their learning tasks in situations of everyday life. In the classroom, such situated learning (Anderson et al., 1996) may be accomplished by simulating daily life situations within immersive virtual reality (Dobricki et al., 2020). This kind of virtual reality (VR) is a type of extended reality technology. Being inside the 3D virtual environment of VR, learners can experience objects or other individuals and interact with them like in everyday life (Dobricki et al., 2021). Hence, VR may serve for the situated learning of eco-friendly food choices particularly well (Markowitz and Bailenson, 2021). In fact, there are already experimental studies suggesting that using VR can support the learning of eco-friendly food choice (Plechátá et al., 2022; Plechátá et al., 2024). However, it has not yet been investigated if this rests upon experiencing the motivational behavior-environment associations introduced above, which depending on the carbon footprint of one's food choices affect oneself negatively or positively. It is, accordingly, an open question, if the viewer-including 3D virtual environment of VR (Dobricki et al., 2021) can serve for this purpose better than a viewer-excluding PC version of it. We have, therefore, started to investigate this potential utility of VR in an exploratory investigation involving two experiments on the level of lower secondary education. For this purpose, we have developed both a VR version and a PC version of a 3D virtual environment and a task to be accomplished within this

environment involving the following experience: the problem that choosing environmentally harming food is accompanied by climate-related environmental alterations affecting oneself negatively by blocking task progression can be solved by replacing this food with eco-friendly food, which is accompanied by the reversal of the environmental alterations affecting oneself positively by unblocking task progression. In a first experiment, we have asked experienced lower secondary school teachers to test both the VR and PC version of our task by accomplishing it themselves and to rate its usefulness to teach eco-friendly food choice. In a second experiment we have subsequently started to explore the learning curve of lower secondary school children accomplishing either the VR or the PC version of the task by measuring their times to solve the problem involved in the task three consecutive times.

2 Materials and methods

2.1 Stimuli and apparatus

All participants were presented with a 3D virtual environment from a first-person perspective. This was accomplished by using the 3D graphics software Unity on a Lenovo Legion 7 computer with an AMD Ryzen 9 processor and an NVIDIA GeForce RTX 3080 graphics card. The virtual environment consisted of a main island on a lake with a wooden house on one side of it and a market stand on its other side. As shown in Figure 1 two other islands with a market stand on each of them were connected to this island by two bridges. To move around the islands, participants could teleport using a controller in their right hand. A basket was attached to and could be moved by a controller in their left hand. One could add or remove food items from the basket using the controller in the right hand. At each market stand, one food item with a high carbon footprint and one with a low carbon footprint were available. When placing a high carbon footprint food item into the basket, the previously sunny sky quickly darkened with clouds, the sun disappeared, heavy rain poured down, and the lake rose, flooding everything in sight (see Figure 2). When replacing the high carbon footprint item with the low carbon footprint item, these climate-related environmental changes were immediately reversed (see Supplementary Movie S1). The two food items at the market stands were the following: Minced beef and potato on the first island, cheese and tomato on the second island, chocolate and apple on the third island. The virtual environment was presented either with the desktop display of the computer or with a stereoscopic motion-tracked Reverb G2 head-mounted display (HMD) from Hewlett-Packard. Wearing this HMD, participants were able to move around and place food items into the basket with the two controllers belonging to the HMD. Being presented with the virtual environment on the desktop screen, they could do this using two Joy-Con controllers from Nintendo.

2.2 Problem-based learning task

On each of the three islands, the following problem-solving task (van Merriënboer, 2013) had to be accomplished. First, the high carbon footprint food item had to be placed into the basket. This

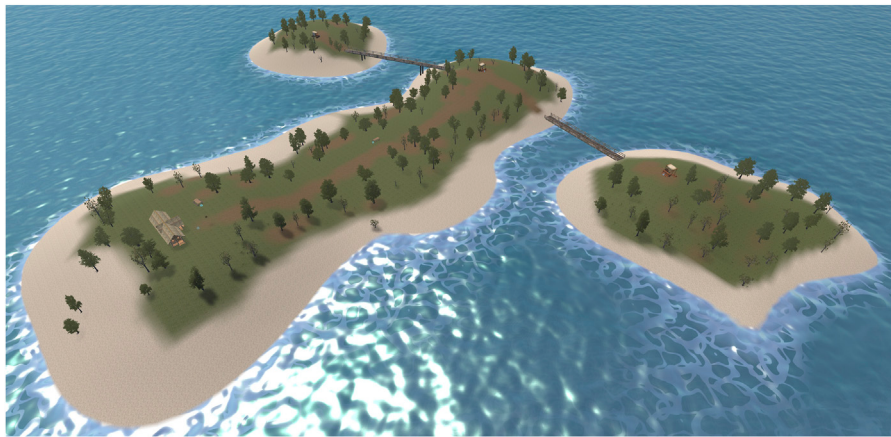


FIGURE 1

Overview of the virtual environment. The 3D virtual environment consisted of three islands. There was a main island with a wooden house on its left side, where participants started the learning task, and the first market stand on its right side. This island was interconnected with two other islands with a market stand on each of them with two bridges.

triggered the rise of the sea level, which prevented that one could get to any of the other islands. Second, this problem had to be solved by replacing the high carbon footprint food item with the low carbon footprint item, which caused the sea level to drop. The initial instruction for this task was as follows: “Please imagine that your grandparents are in the wooden house and want to cook there. They want to cook a stew and prepare a dessert. However, they do not have everything they need for this. Therefore, they send you to get the following three products on the islands in front of you: minced beef and cheese for the stew and chocolate for dessert. Please get these products on the small islands in front of you and come back here. Under no circumstances should you return with an empty basket. The task is only completed when you have placed three food items on the table in front of the wooden house.” At each island, participants were asked to place the food item in the basket that was the one with the high carbon footprint. Immediately after placing this food item in the basket, the climate-related environmental changes occurred, and participants were told the following: “Please find out now what you have to do in order to be able to move on to the next island.”

2.3 Exploratory investigation

The problem-based learning task was investigated using both the VR version and the PC version of the 3D virtual environment described above in an «educator experiment» with teachers and in a «pupil experiment» with school children.

2.3.1 Educator experiment

2.3.1.1 Participants

Ten teachers (3 males, mean age = 44.9 years, SD = 9.2 years) with normal or corrected-to-normal vision participated. This sample size was suggested by *a priori* power analysis (Brysbaert, 2019) specified as follows: $f = 0.3$, alpha error = 0.05, power = 0.8, corr. = 0.8. All participants had been teaching in lower secondary school for at least 7 years. All participants gave their written

informed consent and could have withdrawn from the study at any time. The study was approved by the ethics board of the Bern University of Teacher Education.

2.3.1.2 Experimental design

The study was pre-registered (<https://osf.io/2hv5j>). We used a within-subjects crossover design. There were two experimental conditions. In one condition, the 3D virtual environment spatially included its observer fully, as it was viewed within the head-mounted display. This was the EcoVR condition. In the other condition, the 3D virtual environment spatially excluded its observer, as it was viewed on the desktop display. We named it the EcoPC condition. All participants were exposed to both experimental conditions. The order of the conditions (see data set 1) was determined by the crossover design.

2.3.1.3 Procedure

The procedure was the same in both experimental conditions: First, the use of the virtual environment was explained and briefly practiced. Subsequently, the teachers were informed about the learning task described above and asked to try to place the different food items in the basket at the various market stalls using the controllers. This experience phase was followed by an evaluation phase. In this phase, the teachers were asked to assess EcoVR or EcoPC using the five psychometric questionnaire scales described in the next section.

2.3.1.4 Measures

In the first experiment, the teachers were asked to assess EcoVR and EcoPC using five psychometric questionnaire scales. The first two of these scales corresponded to those of the technology acceptance model (TAM) from Davis (1989) and were each assessed using 6 items (response format: 100 mm visual analog scale, min.: not at all; max.: very much). One of these two scales was used to assess the perceived usefulness of EcoVR and EcoPC for teaching eco-friendly food choice. The other scale was used to assess the ease of use of EcoVR and EcoPC. The third scale was used to

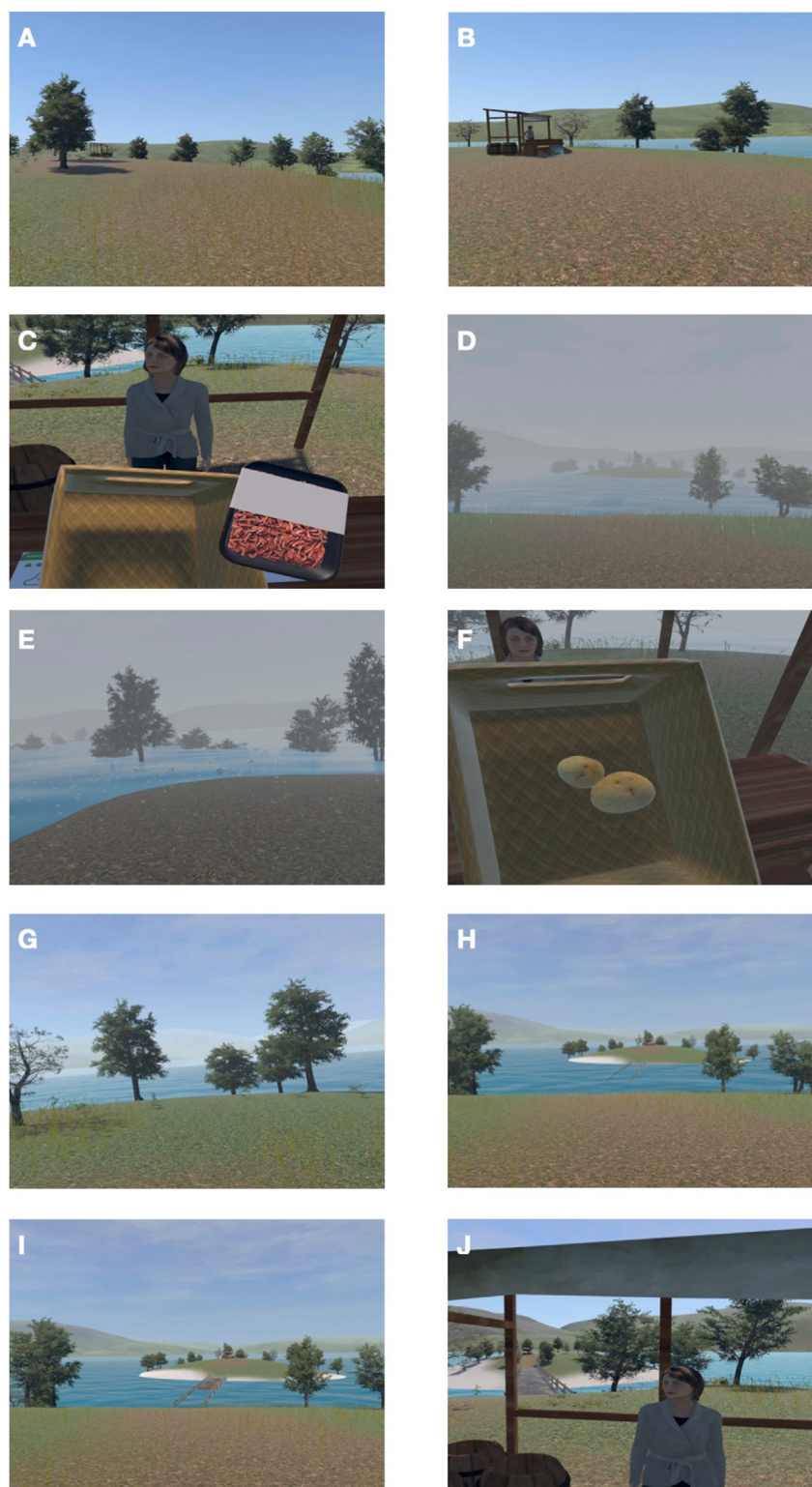


FIGURE 2

Participants' view while accomplishing the problem-solving task. This was the participants' view (A,B) while walking towards the first market stand at which they were asked to first (C) place minced beef in the basket. As a result, the sky darkened with clouds and heavy rain poured down (D), the lake rose, flooding everything in sight (E). When replacing the high carbon footprint food item with a low carbon footprint food item (F), these climate-related environmental changes were reversed (G–J).

evaluate spatial presence, i.e., the feeling of being present in the virtual environment. This scale was assessed using 8 items (response format: 100 mm visual analog scale, min.: not at all; max.: very much) taken from the MEC Spatial Presence Questionnaire (Rössler, 2011). The fourth scale was used to assess immersion. This scale was assessed using 7 items (response format: 7-point Likert-type scale, min.: totally disagree; max.: totally agree) taken from the ARI questionnaire from Georgiou and Kyza (2017). Finally, the fifth scale was used to assess potential negative symptoms using the 16 items (response format: 4-point Likert-type scale, 0 = none, 1 = slight, 2 = moderate, 3 = severe) of the simulator sickness questionnaire (Kennedy et al., 1993).

2.3.2 Pupil experiment

2.3.2.1 Participants

37 children (24 girls, mean age = 12.5 years, SD = 2.1 years) with normal or corrected-to-normal vision participated. This sample size was not based on power analysis, as this study was exploratory by nature. Together with one of their parents, all participants gave written informed consent and could have withdrawn from the study at any time. The study was approved by the ethics board of the Bern University of Teacher Education.

2.3.2.2 Experimental design

In the pupil experiment we used a between-subjects design. It involved the same two experimental conditions as the educator study. In one condition, the 3D virtual environment spatially included its observer fully, as it was viewed within the head-mounted display. This was the EcoVR condition. In the other condition, the 3D virtual environment spatially excluded its observer, as it was viewed on the desktop display. We named it the EcoPC condition. Participants were randomly assigned to one of the two conditions.

2.3.2.3 Procedure

The procedure was the same in both experimental conditions: First, the use of the virtual environment was explained and briefly practiced. Following this introduction phase, the participants were given the learning task described above and asked to accomplish it at the various market stands using the controllers. All participants were guided verbally by the experimenter to the three islands following the same order.

2.3.2.4 Measures

In the pupil experiment, the time to solve the problem involved in the task described above was measured on each island. This was accomplished by measuring the time a participant took from placing the high carbon footprint food item in the basket until replacing it with the low carbon footprint food item. These problem-solving times of the participants on the three islands were used to explore their learning curve in solving the problem involved in the task they were asked to accomplish three consecutive times.

2.4 Data analysis

In the educator experiment, participants' individual scores on the TAM subscales, the spatial presence scale, the immersion scale,

and the simulator sickness scale were determined by calculating their mean rating of the questionnaire items. Subsequently, these scale scores were analyzed in the framework of one-way repeated-measures analyses of variance (ANOVAs) involving an experimental conditions factor and by calculating the effect size η_p^2 . To consider the cross over design these analyses involved also exploring the interaction of the experimental conditions factor and an order of conditions factor. There were no participants that had to be excluded from the analyses in the first study.

In the pupil experiment, the participants' problem-solving times were compared across the two experimental conditions for each of the three islands separately by one-way between-subjects ANOVAs and by calculating the effect size η_p^2 . In addition, it was examined if their problem-solving times decreased from the first to the third island by means of repeated-measures polynomial contrast analyses. There was one participant who had to be excluded from the analyses in the second study due to incomplete data storage.

As for descriptive statistics, we calculated in both experiments the median (*Md*), the lower and upper quartiles, and in the first study also the interquartile range [IQR] for all measures. The statistical analyses were performed with the statistical software SPSS. The visualizations of the statistical results were generated with the ggplot2 package within the statistical software R.

3 Results

3.1 Educator experiment

The statistical analysis of the teachers' ratings across the two experimental conditions yielded the following results: As can be seen in Figure 3 the teachers rated the usefulness of EcoVR for teaching, *Md* = 69.5, IQR [55.3, 81.2], significantly higher, $F(1, 8) = 6.13$, $p = 0.038$, $\eta_p^2 = 0.434$, than the usefulness of the PC version, *Md* = 54.0, IQR [27.6, 71.9]. They also rated the ease of use of EcoVR, *Md* = 73.5, IQR [61.3, 91.3], significantly higher, $F(1, 8) = 9.24$, $p = 0.014$, $\eta_p^2 = 0.507$, than the ease of use of the PC version, *Md* = 47.3, IQR [17.8, 61.6]. The interaction of the experimental conditions factor and the order of conditions factor was not significant neither regarding the usefulness ratings, nor regarding the ease-of-use ratings.

In addition, the teachers' feeling of being present in the virtual environment, i.e., their sense of spatial presence (Figure 3) in EcoVR, *Md* = 83.1, IQR [70.0, 95.3], was significantly stronger, $F(1, 8) = 57.62$, $p < 0.001$, $\eta_p^2 = 0.878$, than in the PC version, *Md* = 29.1, IQR [12.0, 34.9]. The teachers' immersion in EcoVR, *Md* = 5.6, IQR [5.2, 6.0], did not differ, $F(1, 8) = 0.98$, $p = 0.350$, $\eta_p^2 = 0.110$, from that in EcoPC, *Md* = 5.1, IQR [4.1, 10.3]. Finally, there was no difference between the conditions, $F(1, 8) = 2.77$, $p = 0.134$, $\eta_p^2 = 0.258$, regarding simulator sickness symptoms. They were, moreover, very low using both EcoVR, *Md* = 0.2, IQR [0.1, 0.4], and EcoPC, *Md* = 0.1, IQR [0.0, 0.2]. The interaction of the experimental conditions factor and the order of conditions factor was not significant neither regarding the presence ratings, nor regarding the immersion ratings, nor regarding the simulator sickness ratings.

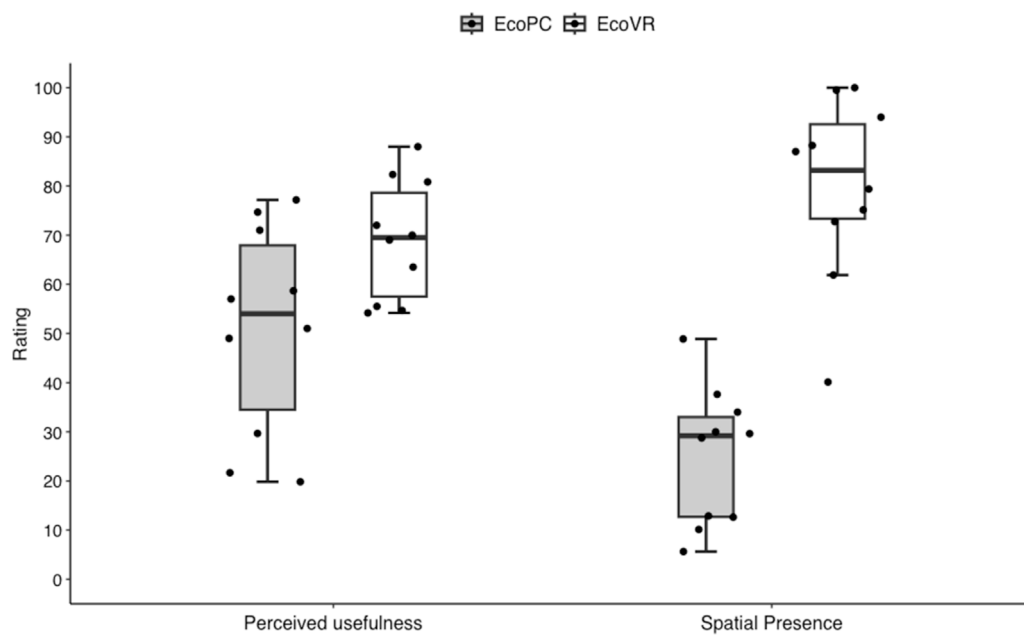


FIGURE 3

Psychometric assessments of teachers. Box-whisker plots of the ratings of EcoVR and the PC version regarding their perceived usefulness for teaching and regarding their sensed spatial presence. Bold horizontal lines show the median of the ratings; boxes show the lower and upper quartiles; whiskers show the furthest data points within 1.5 times the distance to the lower and upper quartiles. Dots depict the individual ratings of the ten teachers.

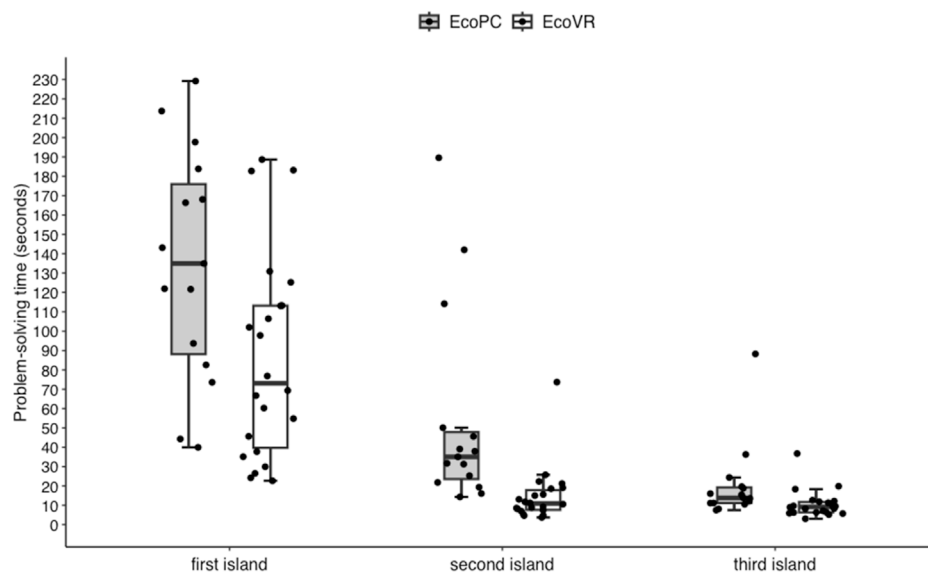


FIGURE 4

Problem-solving times of learners. Box-whisker plots of the problem-solving times on the three islands of the $N = 37$ children using EcoVR or its PC version. Bold horizontal lines show the median of the problem-solving times; boxes show the lower and upper quartiles; whiskers show the furthest data points within 1.5 times the distance to the lower and upper quartiles. Dots depict the individual problem-solving times of the $n = 15$ children using EcoPC and the $n = 22$ children using EcoVR.

3.2 Pupil experiment

The statistical analysis of the problem-solving times on the three islands across the two experimental conditions yielded the following results: As can be seen in Figure 4, participants solved the problem

significantly faster using EcoVR than using EcoPC on the first island, $F(1, 35) = 6.73$, $p = 0.014$, $\eta_p^2 = 0.161$, as well as on the second island, $F(1, 35) = 11.50$, $p = 0.002$, $\eta_p^2 = 0.247$, and on the third island, $F(1, 35) = 4.49$, $p = 0.041$, $\eta_p^2 = 0.114$. The problem-solving times decreased, moreover, from the first to the third island following a

significant linear trend using both EcoVR, $F(1, 21) = 45.05$, $p < 0.001$, $\eta_p^2 = 0.682$, as well as using EcoPC, $F(1, 14) = 49.54$, $p < 0.001$, $\eta_p^2 = 0.780$.

4 Discussion

In the educator experiment the teachers regarded the VR version of our learning task to be more useful for teaching eco-friendly food choices than its PC version. In accordance with this finding, in the pupil experiment the children were learning to solve the problem involved in this task more rapidly using its VR version than using its PC version. Hence, our findings converge in suggesting the following: experiencing motivational behavior-environment associations that depending on the carbon footprint of one's food choice affect oneself negatively or positively using the viewer-including VR version of our task may serve better to support the learning of eco-friendly food choice than using its viewer-excluding PC version.

Our findings are in accordance with meta-analyses of experimental studies suggesting that VR can serve to foster learning (Wu et al., 2020) and specifically the learning of school children (Di Natale et al., 2020). They are also in accordance with previous studies suggesting that VR can serve to foster the learning of eco-friendly behavior (Ahn et al., 2014; Kleinlogel et al., 2023; Stenberdt and Makransky, 2023; Su et al., 2024) and specifically the learning of eco-friendly food choice (Plechátá et al., 2022; Plechátá et al., 2024). Some of these studies found evidence that this learning of eco-friendly food choice in VR was transferred into daily life. Based on our findings it may be hypothesized that this learning transfer is resting upon experiencing and internalizing the motivational behavior-environment associations explored in our investigation. Hence, investigating this very hypothesis in experimental studies may be regarded as one of the most important avenues of future research on the utility of VR for learning eco-friendly food choice. It may be accomplished by the pre-post-assessment of food choice in daily life with a food frequency questionnaire for example.

The transfer of the learning in the VR version of our task into daily life may be facilitated by extending it with an additional learning task that has to be accomplished in daily life for example at home and then reflected upon in school. Hence, using the VR version of our task in formal education may be understood as part of a process that takes children from school to home and back to school again. In such a school-life cycle, the VR of our task may serve as a digital bridge (Schwendimann et al., 2015) or metaverse between the learning of relevant cognitive or behavioral skills in school and the application of them in daily life. Investigating how this integration of our VR-based learning task into educational practice can be achieved may be regarded as a further important avenue of future research.

There are no benchmarks for the perceived usefulness and ease of use scales (Davis, 1989) in research literature. Yet, it may be noted that both the median teacher ratings of the perceived usefulness of EcoVR and those of its ease of use were clearly above the middle of the response scale indicating rather high ratings. As stated above already, the perceived usefulness ratings thereby suggest EcoVR to be a useful digital tool in lower secondary education. Moreover, according to its ease-of-use ratings, EcoVR is easy to use. Whereas

the ease-of-use ratings of the PC version of EcoVR are lower than those of EcoVR itself. This may trigger the suspicion that in the second study, the use of EcoPC resulted in longer problem-solving times, as it might have been more difficult to use than EcoVR. However, the median teacher ratings of the ease of use of EcoPC were very close to the middle of the response scale indicating that also EcoPC was rather easy to use. Hence, the difference between EcoPC and EcoVR regarding their ease of use in the first experiment may explain their difference regarding the problem-solving times in the second experiment only partially. A further study would, accordingly, be needed to clarify to what extent EcoVR is fostering learning due to being easy to use and to what extent due to spatially including learners fully inside its 3D virtual environment (Dobricki et al., 2021).

The climate-related environmental changes that accompany the choice of environmentally harming food in the 3D virtual environment of our learning task are not scientifically proven consequences of the production of such food. Hence, our virtual environment may not serve learners to decrease their psychological distance (Brügger et al., 2015) to the actual environmental consequences of food production. Instead, it is enabling them to experience the association or contingency of their food choices and climate-related environmental changes in a manner that they affect them negatively or positively, when being reversed. These motivational behavior-environment associations may nevertheless be hypothesized to play a role for sensing the distance to actual environmental changes related to environmentally harming human behavior. The reason for this hypothesis is that this psychological distance and the motivational behavior-associations explored in our investigation have in common that both are related to the wellbeing of human individuals (Hickman et al., 2021).

Data availability statement

The datasets of the two studies can be found here: <https://osf.io/6tsze/>.

Ethics statement

The studies involving humans were approved by the Ethikkommission der PHBern, Zentrum für Forschungsförderung. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in both experiments was provided by the participants. In the pupil experiment it was also provided by the participants' legal guardians/next of kin.

Author contributions

MD: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Writing – original draft, Writing – review and editing. MR: Formal Analysis, Funding acquisition, Investigation, Writing – review and editing. SS: Formal Analysis, Investigation, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The reviewer AKB declared a past collaboration with the author MD at the time of review.

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Supplementary material

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