

REDUCING FOOD WASTE WITH VIRTUAL REALITY (VR) TRAINING – A PROTOTYPE AND A/B-TEST IN AN ONLINE EXPERIMENT

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ABSTRACT

Food waste is an important issue in the global warming debate. In this study, a virtual reality (VR) application was built from the insights and requirements of a focus group. The VR prototype was then validated using A/B-testing in an online experiment due to COVID-19 restrictions. VR is considered suitable for transferring information and building awareness regarding the topic of food waste. However, it is necessary to maintain the right balance between an informative and a serious gaming application. VR scenarios that people enjoy using have positive learning effects. Furthermore, scenarios that feature gamification elements are rated more highly regarding intention to use, which, in turn, benefits learning.

KEYWORDS

VR, Food Waste, A/B-Test, Online, Experiment

1. INTRODUCTION

Food waste is an important topic (Jeswani et al., 2021), a real problem (Praktischer Umweltschutz, 2020), and an entire generation has been labelled with the term (Priefer et al., 2014). In households every year, 1.3 billion tons of food are wasted globally, and household-associated food waste accounts for up to a trillion dollars of economic loss (Principato et al., 2021). Furthermore, the topic is relevant because in 2019 worldwide (2600 cities in 160 countries), 7 million people protested openly about climate change (Aaron, 2019). However, empirical evidence suggests that habits can change if food waste is documented (Arnd I. Urban, 2015). Fighting food waste by handing out flyers is not an option as this is neither environmentally friendly nor necessary in a world of smartphones. Until now and as far as the authors are aware, approaches utilising VR remain a research gap. This conclusion is backed by work on the pervasive fridge (a smart fridge concept) by Rouillard, who hypothesises that it may worth investigating augmented reality (AR) to measure the purchased quantities of food and thereby avoid waste. (Rouillard, 2012).

This study aims to reduce food waste through the application of VR in answering the following research question: *How can a VR application contribute to reducing food waste?*

This paper is structured as follows: Following a literature review, there is an overview of the state of the art, a description of the research method, data analysis, discussion, and presentation of findings. To conclude, we address research limitations, further research opportunities, and any implications.

2. LITERATURE

The term “waste” refers to a loss and, in our case, relates to the deliberate or unintentional waste of food. Some authors further distinguish between avoidable and unavoidable waste (Beretta & Hellweg, 2019). Inedible food waste is categorised as “unavoidable”, whereas food waste resulting from a change in preference or distribution problems is labelled “avoidable” (Beretta & Hellweg, 2019). Reasons for avoidable food waste include inadequate storage facilities, expiry dates on products, and personal preferences.

Reasons for food waste are manifold, but Schneider (2008) emphasises socio-cultural aspects and information deficits (Schneider, 2008). Furthermore, portion sizes, sales discounts, and overestimation of the shelf life (Kapp et al., 2017) are reasons why avoidable food waste occurs. Countermeasures such as shopping planning and reducing information deficit (Priefer et al., 2014) are also suggested. Kapp et al. also recommend education and training for individuals as a possible countermeasure (Kapp et al., 2017).

Numerous meta-analyses conclude that VR and AR can positively affect motivation and learning success (Garzón et al., 2019; Radu, 2014; Tekedere & Göke, 2016). For example, gamification specifically can be used for educational purposes and play a role in intrinsic motivation in traffic education (Vogelsberg, 2008). This concept is also used in further education (Fritz, 1997). Serious gaming is a game-based learning approach and extends the pure recreational effect of traditional gaming by providing an added value (Stieglitz, 2015). In pedagogical research, serious games are used to study human behaviour and decision-making (Lang et al., 2012). Furthermore, in certain situations where physical risk exists, simulations and serious games may be a valid training option (e.g. firefighting or flight simulation) (Stieglitz, 2015) since errors could be fatal in real life but not in the world of VR. Hence, using VR simulation for training purposes is much safer.

Although food waste is not usually associated with an immediate risk to life, information transfer via VR seems a good approach to close the food-waste knowledge deficit because positive effects on motivation, learning success, and long-term memory have been reported in empirical studies.

3. METHODOLOGY

This study is composed of two stages or phases. In the first (qualitative) specification phase, a focus group was used to gather specifications for developing the VR prototype before transitioning into the second phase. In the (quantitative) validation phase, A/B-testing in an online experiment with a questionnaire was used to gain insights into which approaches are best to help reduce avoidable food waste.

The first phase can be divided into three steps: (i) preparation, (ii) the focus group round, and (iii) qualitative content analyses. A stimulus was presented at the beginning of the focus group, and guiding questions were used to aid the group discussion. The third step was conducted following the qualitative content analysis, according to Mayring (2015).

Derived from the qualitative phase, the quantitative phase was implemented using LimeSurvey as an online survey tool. As COVID-19 prevented the initially planned lab experiment, a video guiding viewer through the two versions of the prototype (one prototype has gamification elements while the other one does not) was shown to participants in the online survey. The distribution of executable files was considered but dismissed as participants typically do not have the necessary VR hardware or suitable systems. In addition, this could have introduced biases resulting from different hardware configurations. Therefore, randomisation was used to determine which of the two videos was shown to participants.

The gamification prototype (see Figure 1) has high scores, instant graphical feedback, and sound effects, while the non-gamified version does not have these elements.

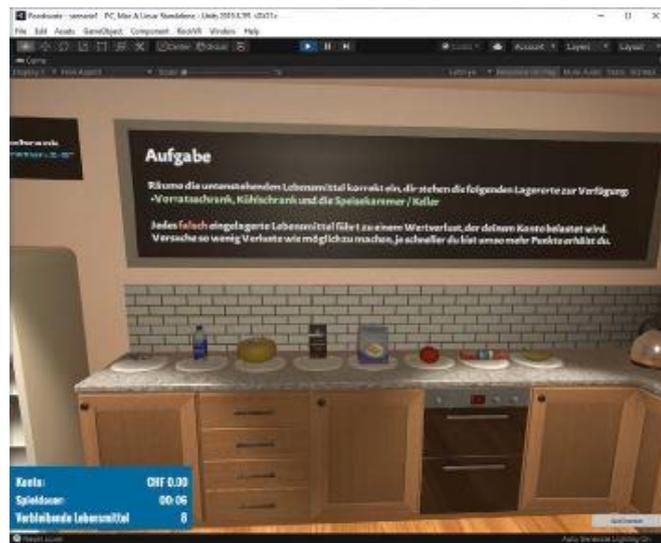


Figure 1. VR prototype

Building on the work of Sagnier et al. (2020), a conceptual model (see Figure 2) was derived and used to derive the hypothesis of this study.

Based on the technology acceptance model (TAM) (Davis, 1986), H1, H2, and H3 were derived (see Table 1 for an overview of all hypotheses), stating the perceived ease of use (PEOU, H1) and perceived usefulness (PU, H2) affecting intention to use (ITU) as well as PEOU affecting PU (H3). Pragmatic quality (PQ) positively affects PEOU (H4a) and PU (H4b); hedonic quality stimulation (HQS) positively affects PEOU (H5a) and PU (H5b); personal innovativeness (PI) positively affects PU (H6a) and ITU (H6b). Venkatesh and Bala (2008) propose that perceived enjoyment (PE) has a positive effect on PEOU (H7a) and ITU (H7b). Furthermore, the authors of this paper hypothesise that the perceived learning outcome (PLO) has a positive effect on the ITU (H8). A note regarding the hypotheses H9–H11 must be made as they were derived after analysing the data and finding significant correlations (see Section 5 and Table 2).

The questionnaire relied on the Likert five-point scale except for the socio-demographic variables, hedonic constructs, and pragmatic quality. The last two were measured on a five-point semantic differential. The PEOU is a 3 item, and PU is a 4 item construct, both based on Kolitz (2008). ITU is a four-item construct drawn from Kolitz (2008), and PE is a six-item construct, based on Balog and Pribeanu (2010). The second items were removed in PE and ITU as they did not apply to the VR scenario. PI has four items based on Lu et al. (2005), whereas PQ and HQS are both seven-item constructs measured by a semantic differential based on Pivec (2006). Finally, PLO is a three-item construct based on Hirdes (2016).

Table 1. Overview of the Hypotheses

#	Text	Result
1	Perceived ease of use positively affects intention to use.	Reject
2	Perceived usefulness positively affects intention to use.	Accept
3	Perceived ease of use positively affects perceived usefulness.	Accept
4a	Pragmatic quality positively affects perceived ease of use.	Reject
4b	Pragmatic quality positively affects perceived usefulness.	Accept
5a	Hedonic quality stimulation has a positive effect on perceived ease of use.	Reject
5b	Hedonic quality stimulation has a positive effect on perceived usefulness.	Accept
6a	Personal innovativeness positively affects perceived usefulness.	Reject
6b	Personal innovativeness positively affects intention to use.	Reject
7a	Perceived enjoyment positively affects perceived ease of use.	Reject
7b	Perceived enjoyment positively affects perceived usefulness.	Accept

#	Text	Result
8	Perceived learning outcome positively affects intention to use.	Accept
9	Perceived enjoyment has a positive effect on perceived learning outcome.	Accept
10	Hedonic quality stimulation has a positive effect on perceived learning outcome.	Accept
11	Perceived usefulness has a positive effect on perceived learning outcome.	Accept

4. DATA ANALYSIS

This section of the paper covers the qualitative and quantitative phases of the research. The qualitative phase was coded with the MAXQDA Analytics Pro 2020 software, and three main categories were identified: (i) development, (ii) design, and (iii) information transfer. In the following paragraphs, aspects mentioned by the focus group participants are described by addressing the categories and subcategories identified in the content analysis.

In the first main category (development), four subcategories were identified: scenario, concept, task, and goals. In the “scenario” subcategory, storage when shopping, minimum shelf-life date, and fridge are reported. Storage covers storage aspects when shopping as well as questions of how to store food once it has been brought home. In “minimum shelf life date”, opening cupboards and deciding if the food is edible based on the shelf-life date is established, while in “fridge”, one must determine whether food must be put in the fridge or not.

In the “concept” subcategory, the product’s life cycle is prolonged or shortened depending on the choice of where to store the food. Players get immediate feedback and responses on the effects their choices have. The game informs players what influences their choices have on the shelf life of the products. For example, a growing or diminishing pile of food waste symbolises whether that decision was right or wrong depending on the storage choice. Furthermore, the game ensures players understand the consequences of their actions.

In the “task” subcategory, a player has a list showing the current and upcoming task. The game does not offer written instructions since the task (storing food purchases at home correctly after returning from shopping) is intuitive. An avatar could provide step-by-step guidance if necessary but not offer hints or explicit instructions.

In the “goals” subcategory, players learn where best to store groceries, decide whether food is still safe or not (even if the shelf-life date has expired), and make informed decisions for themselves. Furthermore, awareness of the consequences of food waste should be heightened.

In the second main category (design), four subcategories were identified: location, interaction, objects, and grocery (objects). In the “location” subcategory, the game should be played where the fridge normally stands. Furthermore, the game should provide a standard use case, common when storing groceries at home, and a familiar environment.

In the “interaction” subcategory, players interact with products and store them. It should be possible to interact and turn the product to see if queues exist regarding the proper storage of the food. Objects that should be present are a fridge, a shelf, and a shopping basket. Familiar and popular foods such as yoghurt or salt should be used in the scenario.

In the third main category (information transfer), two subcategories were identified: feedback and the type of information transfer. In the “feedback” subcategory, textbox information with links to possible storage options is suggested. Feedback is displayed as a textbox, and if a product is not stored correctly, the text turns red. If players make a mistake, they receive a notification about why that action or choice is wrong and why. Standard gamification concepts such as winnable points or coins are also an option.

In the “type of information transfer” subcategory, a combination of visual and textual feedback is proposed, and a focus on visual elements is recommended. Information transfer can also be enhanced with an avatar or mascot.

Based on this qualitative information, the VR prototype requirements are derived and classified as functional (F) or non-functional (NF). The functional requirements are providing a shopping basket, visualisation of task, consequences of storage choices, game progression, and money wasted. Non-functional requirements implemented in the prototype are interaction and intuitive gameplay.

To highlight the consequences of poor storage choices, a price for each food item was set. For example, coffee beans should be stored in the cupboard, meat, fish, cheese, and milk in the fridge, pasta on the shelf, and banana and tomatoes in the pantry. If a wrong storage choice is made, the value of the food is reduced. This system should provide an incentive to avoid food waste within the game scenario. Furthermore, a scoring system with points was introduced to augment the scenario with gamification and provide a further incentive to avoid food waste.

5. RESULTS, DISCUSSION, IMPLICATIONS, AND LIMITATIONS

Data collection was conducted in the spring of 2020 with 95 participants, although some questionnaires were incomplete, leaving 78 for further processing. A control question was used to check if people had actually seen the VR application as they were asked to name the storage option not available in the application. Socio-demographic variables come first, with education being measured by degree because interest in technology, as well as food waste, may be different among these categories.

The sample consists of 29 female (37.2 %) and 49 male (62.8 %) participants. When looking more closely at scenarios one and two, there are 15 and 14 females and 24 and 25 male participants, respectively. The participants are relatively young ($M=36.12$, $SD=9.20$). Regarding education, 39 participants (50%) hold a degree from a university of applied sciences, 13 participants (16.7 %) hold a university degree, ten participants (12.8 %) have a professional diploma, six participants (7.7%) hold an apprentice degree, eight participants (10.3%) hold a college degree, and two participants (2.6%) stated “other educational degree”.

First, the constructs were tested for reliability. Cronbach’s Alpha values of the construct are as follows: PU ($\alpha=.84$), PEOU ($\alpha=.91$), ITU ($\alpha=.91$), PE ($\alpha=.84$), PI ($\alpha=.88$), PQ ($\alpha=.82$), HQS ($\alpha=.91$), and PLO ($\alpha=.92$). The values are all well above the cut off value of .7 generally used in empirical research (Nunally, 1978). Further data analysis could now be conducted.

By comparing the mean values of the two scenarios (with and without gamification), all variables showed significant differences except PEOU and PI (see Table 3). Therefore, the analysis was continued, and correlations were interpreted.

Table 2 shows an overview of correlations. Hypotheses were accepted if correlations between the constructs addressed in the hypothesis correlate significantly. The correlations suggest that H1 must be rejected because the correlation analysis is not significant. However, the constructs in H2 show positive correlations, so H2 is accepted. Similarly, the constructs of H3 shows significant correlations, so H3 is accepted. The constructs in H4a do not correlate significantly, whereas those in H4b do. Consequently, H4a is rejected and H4b accepted. The constructs in H5a do not show significant correlation, so H5a is rejected. However, the constructs of H5b correlate significantly, and H5b is accepted. Both H6a and H6b show no significant correlations and are rejected. The correlation of constructs in H7a is not significant, but those of H7b are, so H7a is rejected and H7b accepted. The constructs in H8 correlate significantly, and H8 is accepted.

During correlation analysis, further hypotheses (H9, H10, and H11) can be derived from the data analysis, not in the TAM referenced in the theory section of this paper. PE correlates with PLO (H9), HQS correlates with PLO (H10), and PU correlates with PLO (H11). Therefore, these hypotheses are added to the overview (see Table 1).

Table 2. Overview of Correlation for Scenario 2 (with gamification)

Hypothesis	Construct 1	Construct 2	Scenario 2	Result
H1	PEoU	ITU	.065	✗
H2	PU	ITU	.717**	✓
H3	PEoU	PU	.373*	✓
H4a	PQ	PEoU	.187	✗
H4b	PQ	PU	.473**	✓
H5a	HQS	EoU	.302	✗

H5b	HQS	PU	.709**	✓
H6a	PI	PU	-.080	✗
H6b	PI	ITU	-.028	✗
H7a	PE	PEoU	.267	✗
H7b	PE	ITU	.613**	✓
H8	PLO	ITU	.628**	✓
#H9	PE	PLO	.599**	✓
#H10	HQS	PLO	.539**	✓
#H11	PU	PLO	.597**	✓

* p < .05, ** p < .01 (both two tailed)

Table 3. Overview of group comparison

Variable	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	CI 95% Lower	CI 95% Higher
PU	-6.301	76	.000	-1.10897	.17600	-1.45951	-.75844
PEOU	-1.245	76	.217	-.27350	.21965	-.71097	.16396
PI	.419	76	.676	.05128	.12225	-.19219	.29476
PLO	-5.096	76	.000	-1.19658	.23480	-1.66422	-.72894
PQ	-3.983	71.204	.000	-.52747	.13242	-.79149	-.26345
HQS	-5.051	76	.000	-.83150	.16463	-1.15938	-.50362
ITU	-6.188	76	.000	-1.39316	.22514	-1.84156	-.94477
PE	-4.602	76	.000	-.75385	.16382	-1.08011	-.42758

6. DISCUSSION

In line with prior research on TAM, PEOU does not show significant effects on ITU, but PU does. Pragmatic quality has effects on PU but not on PEOU. Accordingly, HQS shows positive effects on PU but not on PEOU. PI did not affect PU or ITU, which is somewhat surprising as one could argue that PI may also lead to ITU. PE has positive effects on ITU but not on PEOU. PLO has positive effects on PLO. Therefore, the TAM seems to hold in the context of VR and reducing food waste by immersive experiences.

The dependant variable PLO is noteworthy as correlations were found but were not initially in the derived hypotheses. Nevertheless, data suggests that PE, HQS, PU, and PLO correlate. This is in line with prior research findings; therefore, the conclusions of this study are reported, and the correlations added to the overview as new hypotheses.

7. IMPLICATIONS

Research on VR suggests that this has a positive effect on education (Ai-Lim Lee et al., 2010; Garzón et al., 2019; Radu, 2014). The results of this study confirm that this holds in the contest of food waste too because PE, HQS, and PU positively correlate with PLO. Furthermore, PE positively correlates with ITU the VR application. These preliminary results are promising for organisations seeking to raise awareness regarding the topic and to combat food waste by letting individuals immerse themselves in virtual worlds and discover ways to avoid food waste in real life. Furthermore, the results of this study suggest that this does not have to be an arduous learning path since perceived enjoyment was significantly higher in the gamification enriched VR application than in the non-gamified one. Hedonic quality stimulation was also significantly higher. This supports the suggestion that learning can be a hedonic and enjoyable task, especially when interaction and immersion into virtual worlds are involved. Consequently, creating such worlds is highly recommended because the perceived learning outcome was also significantly higher with the treatment than in the control group.

8. LIMITATIONS

The authors want to highlight that these results are based on correlation analysis. The results should, therefore, be taken as preliminary initial results to inspire further research activities. Furthermore, this study was conducted under the shadow of a worldwide pandemic and the initially planned lab experiment was adapted to enable the quantitative phase to take place online. Consequently, results may differ because the tests were not carried out in laboratory conditions. Empirical research and the meta-analysis mentioned in the literature section of this study suggest that the effects would probably be even stronger if real immersion in the VR application had been experienced. This is because the VR application would leave a greater impression on the user than the online video we were obliged to resort to.

9. FURTHER RESEARCH

This study has a specific scenario, namely, deciding where to store food purchases in the home. Therefore, earlier stages such as the actual shopping or writing of a shopping list may be opportunities for further research towards avoiding food waste. Furthermore, the scenario used in this study is located at home in a familiar environment, so effects resulting from social influences (such as desirability) do not play a role. However, stronger social influences on food-wasting behaviour may well be present in a shared setting such as an office kitchen. Such influences could be further evaluated. A further research opportunity could also arise by varying the price and the products involved. Further research might choose more advanced research methods such as regression and structural equation modelling (SEM) as the correlations reported in this research suggest that direct and indirect effects may be present.

10. CONCLUDING REMARKS

The results of this study are promising and perceived learning outcomes are higher with gamification than without. Furthermore, awareness regarding food waste can be raised with the VR prototype presented in this paper as well as tangible results in terms of food not wasted. The results of this study suggest that this does not have to be a tough learning path but can be pleasurable because learning is based on interaction and takes place in a realistic, albeit virtual context. Therefore, we hope this application will be helpful since its perceived usefulness was significantly higher with the treatment than in the control group. In conclusion, we believe that avoidable food waste can be reduced using the VR application presented in this study, and we invite researchers to contribute and build on these preliminary findings.

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