19th International Conference on Modeling & Applied Simulation
17th International Multidisciplinary Modeling & Simulation Multiconference

ISSN 2724-0037 ISBN 978-88-85741-48-5 © 2020 The Authors.
DOI: 10.46354/i3m.2020.mas.018

Next Level Training in Logistics: Evaluation of a Virtual Reality based Serious Game for Warehouse Logistics

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Abstract

Serious Games have a great potential to professionalise the training of employees in intralogistics. Using virtual reality (VR) and established serious game mechanics trainees can be prepared for their future tasks in logistics in a motivating, individual and sustainable manner. The Fraunhofer IML developed a VR-based learning game for warehouse logistics in cooperation with the DEKRA Akademie that simulates the receiving goods process. It will be included as a training module in the DEKRA Akademie portfolio. An evaluation study on cognitive and physical ergonomics explored the human-machine interaction and the suitability of the virtual training for warehouse trainees. Study results clarify that it is a user-friendly, motivating educational game. The implementation concept of the VR application is presented as a direct consequence of the Fraunhofer IML VR strategy.

Keywords: serious games in virtual reality, virtual educational training for intralogistics, cognitive ergonomics, physical ergonomics

1. Introduction

The recruitment and long-term retention of competent employees is a major challenge for logistics companies. Because of their high flexibility and speed, humans remain still important for simple, repetitive activities such as packaging or picking within automated warehouse systems (Sailer, 2016). These so-called simple work activities can be carried out after short qualification processes, as no relevant vocational training is required (Hirsch-Kreinsen, 2016). In order to enable even unskilled workers to get a sustainable training and, if necessary, to overcome language barriers, new, digitized variants of employee qualification are being developed and tested. Serious games, that means digital training methods with a gaming approach, are suitable for providing knowledge about process and quality requirements in a standardised and company-specific manner. Another advantage of serious games is that newly acquired skills can be tested and evaluated directly or mistakes can be minimised from the beginning. In addition, they offer a cost- and time-saving supplement to traditional training methods, because they are not confined to a specific location and combine practical training with theoretical background knowledge. The learning success of serious games is also higher than that of traditional learning methods, which is demonstrated by an increase in performance in the real setting (Clark et al., 2017). The higher the degree of virtuality of a training, the deeper the participants immerse in the simulated working environment and are less distracted during learning (Lamb, 2016). With VR the immersion can be maximised. Due to the virtual representation of work scenarios, participants can train their future activities realistically. Classical game mechanics such as a story line, levels, high scores, best times or badges motivate the participants dealing with the learning material more intensively (Arnab et al., 2015). A big advantage is that, if the participants have different levels of knowledge, the learning speed of each participant can be individually adjusted. VR-based serious games have the potential to be established as an essential future technology for the training of employees in logistics.

2. Previous VR trainings at Fraunhofer IML

Virtual trainings for warehouse logistics are an integral part of the overall VR concept developed by Fraunhofer IML. It includes planning visualization, replanning and educational training and therefore means maximum flexibility in planning and operation of warehouses. All mentioned process steps can be analysed and secured by key figures, which are partly collected by studies and modularised implementation partly by automated simulation. The flexibility results from a concept that is described in caption 3.4. So far Fraunhofer IML has developed the following VR trainings.

Figure 1. PackNick. The user is guided through every step by the game's audio feedback.

2.1. PackNick

In PackNick, the user trains the essential processes and handling of packaging activities, such as operating the associated computer system, reading packaging descriptions, using work equipment such as scanners, label printers and parcel tape dispensers, and selecting the correct packaging materials (Fig. 1). Game elements, such as points and a list of best scores, motivate the user to achieve a personal best.

2.2. PickNick Voice

To learn how to use a pick-by-voice system for order picking activities the serious game PickNick Voice was developed. In this game, the user learns the basics of picking in addition to operating the Pick-by-Voice system. The learning content is provided by a story line about the robot Klausi, which embodies the teaching guide and the pick-by-voice system in VR (Fig. 2). The actual learning process is thus unconsciously perceived by experiencing the story and the users are motivated by badges that they have to earn.

2.3. LiftNick

The learning software LiftNick, a serious game for forklift truck drivers, enables process and layout training as well as training the awareness of hazards and rules (Fig. 3). The user receives permanent visual feedback on his actions as well as a visual process control. In contrast to other forklift simulators, this training utilises conventional consumer hardware such as a steering wheel, pedals, joystick and a motion platform. This keeps the hardware acquisition costs comparatively low. Voices from practice show that the feedback from the participants is extraordinarily good, both in terms of driving behaviour and fun and effectiveness of learning.

Figure 2. PickNick Voice. The robot Klausi guides the user through the game.

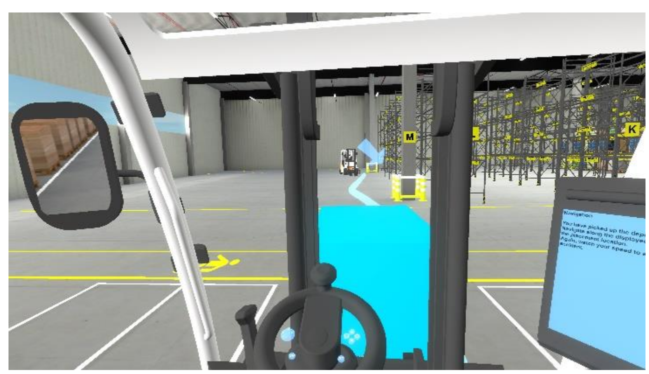

Figure 3. LiftNick. The user is guided by markers and symbols.

3. Project for VR training "receiving goods" with DEKRA Akademie

3.1. Motivation

Due to the rapidly advancing digitization in the field of logistics, the competence requirements for employees change very quickly. DEKRA Akademie GmbH, one of the largest private training companies in Germany with core competence in the areas of transport, warehouse and hazardous goods logistics, is thus faced with great challenges in the implementation of a modern and workplace-oriented qualification system. By using a virtual training, DEKRA Akademie can respond even better to the needs of customers in their respective life and career situations. In addition, the human being can continue to exist in the warehouse as a reliable and flexible knowledge resource.

Based on the previous technical developments in the field of serious gaming at the Fraunhofer IML, a VR-supported learning game was developed for DEKRA Akademie as part of the transfer project "VR-Schulung in logistischen Ausbildungsmaßnahmen für Geringqualifizierte [VR training in logistical training for low-skilled employees] – VilAG", which is supported by the research project "Innovation Laboratory Hybrid Services in Logistics". A core process from an existing qualification module of DEKRA Akademie was implemented as VR training, integrated into the overall qualification measure and evaluated by means of an evaluation study on cognitive and physical ergonomics. The project enables DEKRA Akademie to evaluate virtual trainings and to include the VR technology in its further training portfolio in the long term.

3.2. Goods receiving as a future training module

As a new training module to be implemented for the DEKRA Akademie portfolio, the process of goods receiving was selected. The goods receiving procedure is an important warehouse function that helps keep track of incoming stock and furthermore meets the various requirements of serious games: On the one hand, the process offers a high degree of user interaction within the game, which is beneficial for the learning effect of the training participants. On the other hand, the training module of the goods receiving is highly relevant within the entire training portfolio and can be integrated very well into the existing training process.

3.3. Game concept

The story line of the VR training of the goods receiving process consists of the following scenario: The initial situation in the training is that the user is supposed to receive goods from the truck driver Ingo (abbreviation for incoming goods), which have just arrived in the warehouse (Fig. 4). The goods receiving procedure consists of six steps, which are played by the user one after the other: Check and inspection of

- Delivery address,
- Delivery authorization,
- Delivery time,
- Parcel quantities,
- Physical integrity of goods and
- Transport packaging

The playful approach of the VR training is realised in the form of funny dialogues with the truck driver Ingo and several persons from different departments in case of disturbances in the warehouse. In addition, the truck driver Ingo acts as a trainer who introduces the user to each step of the process by giving feedback regarding the user's work activity (Tutoring system).

The user (or the physical trainer) can adjust the game to the player's current learning objectives by selecting certain disturbances in the process to occur. Each of the process steps mentioned above can be setup with errors that the user has to observe in order to successfully complete the game. The user can select each process step to train certain disturbances or chose the random option where the game randomly chooses one (or none) error to occur.

3.4. Implementation concept

The game is implemented based on the VR concept developed by Fraunhofer IML. As already mentioned, the VR training is designed to generate maximum flexibility through modularisation. This modularisation can be seen in the separation of the warehouse layout (i.e. the graphical representation of the game) from the process design (i.e. game logic). The game is built through these two separate layers (Fig. 5). Therefore, warehouse layouts can be used for any available process training and the layers can be linked together with little effort.

Figure 4. InGo. The truck driver Ingo helps the user during the whole goods receiving process.

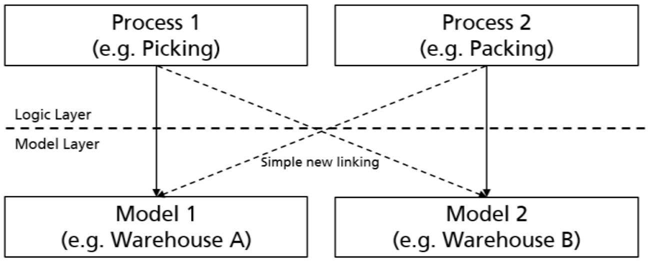

Figure 5. The layer concept for Serious Games developed by Fraunhofer IML.

As Unity 3D® is used as the technical basis, the layers are represented by scenes which are loaded additively and connected to each other via an interface. The model layer provides the logical layer with position information of critical, i.e. process-relevant objects via this interface.

The processes themselves are modularised down to their atomic actions like scanning a barcode, picking up a certain item or reaching a certain destination. These actions are linked in a process designer, which is implemented as an extension of Unity and facilitates the referencing of scene objects. The process designer enables the Fraunhofer IML to react comfortably to changes in certain process steps as logistics processes evolve. This guarantees that virtual trainings are up-to-date and individualised with regard to company-specific requirements with comparatively low programming effort.

3.5. Evaluation study on cognitive ergonomics

To proof the operability and utility for trainings in the intralogistics sector, the VR-based serious game "InGo" was evaluated in a research study on cognitive and physical ergonomics.

3.5.1. Research design and study sample

The evaluation study was conducted with 19 training participants (13 men, 6 woman) at the DEKRA Akademie GmbH in Dortmund, Germany. The age distribution (25-34 years: 10 %, 35-44 years: 58 %, 45-54: 11 %, >54 years: 21 %) and also the different educational levels of the study sample show that the majority of participants pursue the training as a specialist in warehouse logistics as a second educational path.

The study was conducted with each participant individually. After a short welcome and project presentation, each person had to fill in a first paper-pencil based questionnaire about their current affect situation (15 min.). Afterwards, the participants had time to get to know the VR technology. For this, each participant first had to complete the Steam® HTC-Vive® Tutorial to become familiar with the virtual environment and to learn the handling of the controllers (15 min.). Afterwards, all participants played the VR-based serious game "InGo" under the guidance of the study director (30 min.). Following this, each participant evaluated the VR training with validated questionnaires under the guidance of another study supervisor and subsequently answered various questions during a personal exploratory interview (60 min. in total).

In the questionnaire survey, besides socio-demographic questions, questions regarding the personal technology commitment and the current affect situation were raised. Participants were asked to assess their current affect situation before and after the training to experience an improvement or impairment of the well-being as a result of the learning game (Krohne et al., 1996).

In addition, participants should evaluate the training in terms of cognitive and physical ergonomics. For example, recorded concepts of cognitive ergonomics were usability (Brooke, 1996), user experience (Laugwitz et al., 2008), task difficulty (Baltrusch et al., 2018), workload (Hart and Staveland, 1988) or the sense of presence experienced in the virtual environment during the training (Schubert, 2003). Also of interest was whether the training improved the motivation to learn and thus had a positive effect on learning success of the participants. For this purpose, the intrinsic motivation of the participants during the educational game was analysed (Wilde et al., 2009). To measure physical ergonomics, appropriate paper-pencil questionnaires were selected. Questions of physical ergonomics were i.e. wearing comfort (Baltrusch et al., 2018), ocular strain or musculoskeletal complaints (Jaschinski et al., 2015) while interacting in the virtual environment.

Since the personal attitude towards technologies can influence the perception during a virtual training, various technology-related personality traits were recorded, such as acceptance, agency and control beliefs regarding new technologies (Neyer et al., 2016). As it is known that there are differences in the tendency of individuals to experience presence in movies, games or generally in virtual environments, the capability of individuals to be involved or immersed in virtual worlds was explored (Witmer and Singer, 1998).

Finally, exploratory interviews were conducted to find out advantages and disadvantages of the VR training. For this, participants were asked individually what they liked best about the use of the virtual training, what difficulties and problem points they could name and whether there were any suggestions for improvement.

3.5.2. Results of the questionnaire survey

Regarding technology-based personal information, results make obvious that acceptance (*MW* = 3.6; *SD* = 1.0), agency beliefs (*MW* = 4.3; *SD* = 0.6) and also control beliefs (*MW* = 3.4; *SD* = 0.8) with respect to new technologies were rather high among the study sample. This means that the participants were generally positive about new technologies. Individual tendencies to immerse in a virtual environment were at a moderate level (*MW* = 3.3; *SD* = 0.8). Likewise, the tendency to remain focused on current activities (*MW* = 3.8; *SD* = 1.0), the tendency to become involved in activities (*MW* = 3.2; *SD* = 1.0) and the tendency to play video games achieved moderate values (*MW* = 2.9; *SD* = 1.4). From this it can be assumed that the participants were not completely immersed in the virtual training world.

To achieve a learning effect in a training, it should be designed in such a way that the participant can develop a high intrinsic motivation. The subscale interest or enjoyment shows that the sample was highly motivated during the VR training (*M* = 3.5, *SD* = 0.7). Both positive predictors of intrinsic motivation, namely perceived competence (*M* = 2.7, *SD* = 1.0) and perceived choice (*M* = 2.8, *SD* = 0.9), reached moderate average values. Perceived pressure or tension, a negative predictor of intrinsic motivation, was quite low (*M* = 1.2, *SD* = 1.0). It can be concluded that the participants had a relatively high motivation to learn. Good usability can be said to be achieved when the goals of satisfaction, efficiency and effectiveness in the performance of a work task, in this case the virtual training, are achieved (DIN EN ISO 6385). The usability of the VR game reached an average SUS score of *M* = 66.8 (*SD* = 16.3) which can be interpreted as a "good" rating (Bangor et al. 2009). It is noticeable that the subjective usability assessment varies from "bad" (SUS Score *Min* = 37.5) to "excellent" (SUS Score *Max* = 100).

To proof whether participants had a sense of presence in the virtual warehouse, three subscales and one additional general item were measured: Spatial Presence rated the sense of being physically present in the virtual warehouse. The attention devoted to the virtual learning environment and the involvement experienced was measured with the subscale involvement. The subjective experience of realism in the virtual reality was analysed with the subdimension experienced realism. Both, spatial presence (*M* = 1.4, *SD* = 1.0) and the general sense of presence (*M* = 1.4, *SD* = 1.5) were considered positive. The subscales experienced realism (*M* = 0.47, *SD* = 1.3) and involvement (*M* = 0.1, *SD* = 1.0) only reached a neutral evaluation.

User experience, which is positively correlated with usability (DIN EN ISO 6385), can be categorised into three dimensions attractiveness, pragmatic quality (PQ: Perspicuity, efficiency, dependability) and hedonic quality (HQ: Stimulation, novelty). All three main dimensions scored positively, PQ and HQ were rated comparably good (PQ: *M* = 1.5, *SD* = 0.7; HQ: *M* = 1.6, *SD* = 0.7). Furthermore, the six underlying subscales of the user experience have received positive ratings on average (Tab. 1).

According to the user experience ratings, the current affectivity before and after the VR training was also predominantly positive (pretest positive affect: *M* = 3.3; *SD* = 0.7; posttest positive affect: *M* = 3.6; *SD* = 0.8; pretest negative affect: *M* = 1.4; *SD* = 0.4; posttest negative affect: *M* = 1.4; *SD* = 0.5). There was a tendency for participants to feel slightly better after the VR training ($Z = -2.0$; $p < .10$).

The overall workload during the VR training was evaluated on average as moderate (Raw TLX: *M* = 31.3; *SD* = 17.8) (Grier, 2015). This corresponds to a task difficulty that was also assessed at a moderate level (*M* = 28.9; *SD* = 22.5). This means that the participants were neither overchallenged nor underchallenged during the training. The characteristics of the individual six workload subscales ranged from very low to very high load (Tab. 2). The mental and temporal demands were the greatest, i.e. the participants felt mentally and temporally stressed.

Furthermore, various components of intuitive use as well as a global judgement on the perceived intuitiveness of the VR technology were recorded. The global measure of perceived intuitiveness is quite high (*M* = 5.2; *SD* = 1.4).

Table 1. Descriptive statistics of the user experience subscales.

User Experience	*Min*	*Max*	*M*	*SD*
Attractiveness	0.2	2.8	2.0	0.8
Stimulation	0.8	3.0	1.9	0.7
Novelty	-0.3	3.0	1.3	0.8
Efficiency	0.5	3.0	1.8	0.7
Perspicuity	-0.3	3.0	1.5	1.0
Dependability	0.0	2.8	1.1	0.8

Note. Min = Minimum, Max = Maximum, M = Arithmetic mean, SD = Standard deviation

Table 2. Descriptive statistics of the Workload subscales.

Workload	*Min*	*Max*	*M*	*SD*
Mental demand	5	100	43.7	28.3
Physical demand	0	85	26.3	25.5
Temporal demand	0	100	37.6	28.2
Performance	5	75	26.3	17.4
Effort	0	95	31.1	30.9

Note. Min = Minimum, Max = Maximum, M = Arithmetic mean, SD = Standard deviation, performance reaches from good to bad

The subscales effortlessness (*M* = 4.9; *SD* = 1.2), magical experience (*M* = 5.5; *SD* = 1.4) and the ability to verbalise (*M* = 5.2; *SD* = 1.6) achieved quite high ratings. Thus, the interaction with VR technology is therefore experienced as effortless, extraordinary and fascinating. In addition, the temporal course of the interaction can be well described and remembered, which suggests a logical or plausible sequence of operating steps. Moderate values for gut feeling indicate that the interaction with the product was perceived as being guided by reason and less by emotion (*M* = 3.5; *SD* = 1.3).

Furthermore, user impression was recorded, such as feelings of discomfort, handling characteristics of the VR hardware, range of movement and experienced efficacy. The general wearing comfort was rated as above average (*M* = 7.6; *SD* = 1.7). Both donning and doffing (*M* = 7.9; *SD* = 1.6) and length adjustment (*M* = 8.1; *SD* = 1.4) were found to be predominantly simple. The freedom of movement was only perceived as slightly restricted (*M* = 6.6, *SD* = 2.2). The efficiency results were also very satisfactory: The experienced task support during the training was considered high (*M* = 7.1; *SD* = 2.0). Finally, with regard to the assessment of visual and physical strain, it can be concluded that the participants were hardly stressed by the VR glasses (dizziness: *M* = 1.4; *SD* = 0.6; ocular strain: *M* = 1.6; *SD* = 0.8; musculoskeletal strain: *M* = 1.3; *SD* = 0.3; headache: *M* = 1.2; *SD* = 0.7). The dynamic vision during head movements was rated to be good (*M* = 5.4, *SD* = 0.9).

3.5.3. *Results of the exploratory interviews*

Participants were asked individually in exploratory interviews what they liked most about using the virtual training, what difficulties and problem points they can tell and whether there were any suggestions for improvement. The results of the open questions are presented below in the form of word clouds (positive aspects in Fig. 6; negative aspects in Fig. 7).

Overall, participants expressed more positive (62 mentions) than negative aspects (51 mentions). The proximity to reality (10 mentions) and the fact that the VR game is impressive (9 mentions) were emphasised positively (Fig. 6). Further positive aspects are that there is a good user guidance, that the VR game is a great learning aid and is very interesting (6 mentions each). It was mentioned four times that the game is clearly structured and has a good design quality. Furthermore, it was positively mentioned that the VR training was diversified, modern, motivating, user-friendly, fun (3 mentions each) and easy to learn (2 mentions).

Figure 6. Word cloud with positive aspects of virtual training (*N* = 19)

Figure 7. Word cloud with negative aspects of virtual training (*N* = 19)

On the other hand, there were mainly problems with the hardware (Fig. 7), that the wired VR glasses were a tripping hazard for participants (9 mentions) and that the handling with controllers was considered difficult (7 mentions). Comparatively often it was mentioned that the VR glasses were perceived as uncomfortable and the virtual environment was fuzzy (6 mentions each). Further points of criticism were that there were problems in reading and that more practice would have been necessary (4 mentions each). There were also difficulties with the tutorial and the VR environment was described as unrealistic (3 mentions each). Less frequently, it was mentioned that physical complaints occurred like sweating or that the VR glasses were uncomfortable. Both software and hardware problems were mentioned very rarely.

4. Summary and outlook

VR-based serious games represent innovative training formats that are suitable for training employees for intralogistics activities in a playful and motivating way. The goal of virtual learning worlds is to train both the process understanding and the quality awareness of future warehouse workers in a standardised, intuitive and sustainable way. In this way, possible errors can be counteracted as early as the familiarization phase. Building on the virtual training courses already designed at the Fraunhofer IML for the activities packaging, order picking and forklift driving (Storage, transfer and retrieval), the process of receiving goods was being implemented as a training module for the DEKRA Akademie. In addition, to an even more efficient training process, DEKRA Akademie also hopes to reduce the workload of the training personnel and increase the learning success of the training participants. By using digital training modules, DEKRA Akademie can respond even more flexibly to customer requirements and offer individual training formats depending on the customer's requirement profile.

In line with the overall VR strategy of the Fraunhofer IML, the virtual serious games have been largely modularly structured so that, for example, locations or sub-processes can be exchanged without having to design and develop the training courses from scratch. This modular system is constantly being expanded and made more flexible and is becoming more and more the focus of attention, in particular for small companies. Especially in connection with the VR hardware, which has become very inexpensive today, the equipment with individualised trainings is becoming more and more affordable for smaller companies.

Especially the training of unusual situations that do rarely happen is valuable. Therefore, the user can choose from a pool of process errors or train a random one. Then, all disturbance events and corresponding expected actions of the user are predetermined before starting the process. A stochastic discrete-event simulation could be a powerful enhancement to further increase the training effect and variety of training situations (Longo et al., 2019).

Overall, the study results show that the VR training InGo is a user-friendly learning method. Even if not all participants have the personal skills to immerse themselves in virtual worlds or are generally sceptical about new technologies, the learning content was conveyed in a way that was both motivating and intuitive. A positive result is that the participants felt well supported in their learning process and left the training with a positive feeling.

In future research studies, a direct comparison between VR training and traditional training methods should be carried out. This will provide clearer indications of the advantages and disadvantages of virtual training. In addition, it can be expected that the most frequently mentioned issues such as cable interference and controller handling problems can be covered by newer generations of VR hardware which can be investigated in further studies. Also the mentioned reading difficulties can be reduced by improving the graphical user interface in VR. Especially the guidance of the user through the game itself has to be optimised to reduce the mental demand and the overall workload. In the future, a great potential is seen in virtual training worlds.

Funding

The project "VR-Schulung in logistischen Ausbildungsmaßnahmen für Geringqualifizierte [VR training in logistical training for low-skilled employees] – VilAG" was carried out together with the project partner DEKRA Akademie GmbH as a transfer project within the interdisciplinary research project "Innovation Laboratory Hybrid Services in Logistics".

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