Investigating learners' motivation towards a virtual reality learning environment: a pilot study in vehicle painting

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***Abstract*—The *HandleVR* project develops a Virtual Reality (VR) training based on the 4C/ID model [1] to train vocational competencies in the field of vehicle painting. The paper presents the results of a pilot study with fourteen aspirant vehicle painters who tested two prototypical tasks in VR and evaluated its suitability, i.a. regarding their learning motivation. The results indicate that VR training is highly motivating and some aspects (e.g., a virtual trainer) in particular promote motivation. Further research is needed to take advantage of these positive motivational effects to support meaningful learning.**

***Keywords*—virtual reality, motivation, immersive learning environments**

I. Introduction

Virtual Reality (VR) technologies are increasingly promoted as a promising educational tool in diverse training settings [2], [3]. They offer a variety of exciting and enjoyable learning experiences and can elevate learners' situational interest and motivation more than conventional learning media [4]-[8]. Immersive environments create a sense of presence, which motivates the learners to pay attention to the content, thereby causing the learner to process the material more deeply and persisting throughout the entire learning session, which can lead to better learning outcomes than other learning media [9]-[11].

The purpose of this pilot study is to explore, which aspects of VR learning environments, designed according to an instructional design model, are stimulating learning and which aspects are less motivating. First, I will introduce the construct motivation, following its importance in the context of VR learning environments. Subsequently, the underlying VR learning environment, methods, and results of the pilot study building upon it will be explained. Finally, I will identify factors within VR learning environments that influence motivation and that should be considered when conceptualizing highly motivating and meaningful learning scenarios.

II. Theoretical Background

A. Motivation

Motivation is defined as an internal state or condition that activates, guides, maintains, or directs behavior [12]. This psychological factor has found to affect learning effectiveness by many researchers [13]-[18]. High motivation is associated with situational interest. According to the interest theory [19], [20], situational interest can stimulate and boost individual motivation to learn [21]-[23]. Those who are highly motivated are more likely to engage, put in more effort to understand the learning material, and be resilient when overcoming obstacles in understanding [21], [24]. A high level of motivation may cause the learner to stay focused and invest more cognitive resources to difficult parts of the task.

B. Motivation within VR learning environments

In VR learning environments, motivation is a potentially important but an understudied factor. However, some studies have already shown that VR learning applications can spark situational interest and trigger a high level of motivation [25], [26]. Further studies pointed to a positive correlation between motivation and learning effectiveness [27]-[29]. Some research is focused on specific aspects of VR learning environments that trigger motivation. Next to motivating effects through the realism of the scene, dynamic displays, and close-loop interaction [29], physical interaction facilitates the learning motivation [30]. Incorporating an intelligent feedback system for progress will boost learner's self-efficacy as well, which would in turn enhance motivation [11]. Other studies reported that a strong impact on motivation can be obtained through a virtual learning companion or teacher, that provides constructive feedback, shows sensitivity and interest to the individual learning progress, and displays enthusiasm when achieving good results and disappointment when failing [10], [31], [32]. Thus, [33] noted that "lifelike, interactive digital characters, serving as mentors and role-playing actors, have been shown to significantly improve learner motivation and retention." (p.75).

III. Methods

A. VR research project

In the research project *HandLeVR* [1], a highly validated instructional design model, namely the 4C/ID model [1], is applied to enable competence-based training in the field of vehicle painting resulting in the "VR-painting shop". The model was originally developed to train complex cognitive skills and provide instructional principles to design effective training programs. It focuses on four principles of meaningful-learning. "Learning tasks" (1) imply that learners should train whole and authentic tasks with rising complexity over time. In *HandLeVR*,

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this was achieved by implementing customer orders which are taken from a German company for car painting. Furthermore, the training of vehicle painters inherently requires a considerable amount of instructions and feedback regarding correct procedures and strategies as well as motion sequences. Procedures and strategies are addressed by the principle of "supportive information" (2), which supports schema construction and the development of mental models. In *HandLeVR*, these information units were presented by oral or written statements of a human virtual trainer, by slide shows (e.g., about safety at work), by tables (e.g., about performance criteria) and by short videos (e.g., a trainer explains how to prepare work pieces). Motion sequences are addressed by the principle of "just-in-time-information" (3), which provides context-specific information and corrective feedback during task execution. In *HandLeVR*, "just-in-time-information" is provided by tools indicating the right motions during the painting process (e.g., a beam that displays the distance to the workpiece, see figure 1). Last, the 4C/ID model offers guidelines for "part-task practice" (4) for highly routine tasks. "Part-task practice" is particularly important in vehicle painting as the training of correct and smooth hand-eye-body-coordination. In *HandLeVR*, additional training opportunities with simplified rectangular workpieces are incorporated. After each learning task, the apprentices receive feedback on their performance in the form of individual performance parameters (e.g., paint consumption) and in the form of a heat map, which shows the coating thickness on the workpiece in color (see figure 2).

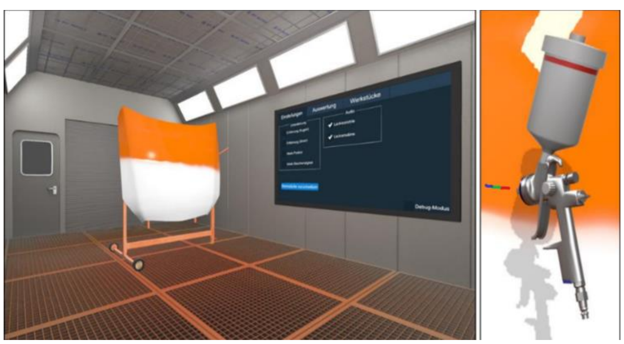

Fig. 1. Paint booth with a workpiece and the user interface on the wall (left image) and the current version of the paint gun indicating the right distance (right)

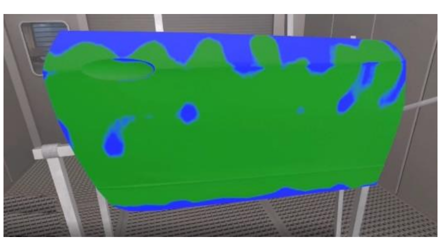

Fig. 2. Heat map of a workpiece (red: too thick, green: right thickness, blue: too thin).

B. Pilot Study

Within the pilot study, the first prototype of "VR-painting shop" is evaluated. Therefore, the study aims to investigate the general motivation due to the VR learning environment as well as specific aspects of VR learning environment that trigger learning motivation. We hypothesize that (1) the "VR-painting shop" itself is in general a highly motivating learning tool and (2) especially certain instructional principles (e.g., "supportive information", "just-in-time-information", constructive feedback by an intelligent virtual trainer) increase learning motivation.

Within one and a half years of project work, two prototypical "learning tasks" were developed for VR according to 4C/ID model [1]. This was done in cooperation with trainers and trainees in vehicle painting. The tasks have been evaluated and re-developed iteratively. Both "learning tasks" illustrate a single layer refinishes on two different workpieces. A permanently present virtual trainer guides the apprentice through the tasks. In addition to the painting process itself, "learning tasks" contain several permanently available „supportive information", mostly for preparatory and follow-up activities (e.g., self-made videos by apprentices about using personal protective equipment). During the painting process, the apprentice is supported by a beam indicating the right distance to the workpiece and by constructive oral and written feedback by the virtual trainer. The feedback system is adaptive and therefore intelligent. Feedback is provided individually and depends on the learner's performance (e.g., visual and acoustic signals in case of errors). Following the "learning tasks", simplified training opportunities with additional support are offered.

In a two-day workshop, aspirant vehicle painters performed these "learning tasks". They work on the tasks alone and independently without external help. Afterwards, they filled in some questionnaires and were part of a discussion group. The participants were fourteen aspirant vehicle painters recruited from a large training provider near Potsdam, Germany (6 women, ages 17-24, M = 19.14, SD = 2.21).

The paper-based materials consisted of several questionnaires. The FAM [34] records the current motivation in learning and performance situations. It consists of four scales (fear of failure, interest, probability of success, challenge) with a total of 18 items (e.g., "I may not be able to complete the task."). Within a discussion group, aspirant vehicle painters were asked to name more and less motivating elements of the "VR-painting shop" regarding learning success.

IV. Results

Means and standard deviations of the sample were calculated (fear of failure: M = 1.97, SD = 0.95; interest: M = 4.36, SD = 1.21 ; challenge: M = 4.95, SD = 0.96 ; probability of success M = 5.97, SD = 1.01) and compared to different standard values of non-immersive learning tools [34], [35]. Compared to these standard values, the motivation concerning "VR-painting shop" is comparable or even higher. Especially the "fear of failure" is less and the "probability of success" higher, partly more than one standard deviation. Results of the discussion group revealed that interaction with the virtual trainer and "supportive information", particularly the videos, were helpful and motivating. Many aspirant vehicle painters emphasized that they enjoyed communicating and interacting with the virtual trainer as well as receiving feedback from him. They stated that they are pleased to meet him again in the further "learning tasks". This result is consistent with prior research that stress the importance of a virtual teacher [31]-[33]. Future VR learning environments should rely on artificially intelligent trainers to individually support learners and therefore increase learning success. “Supportive information” was described as “nice variety through media change” and “refreshingly different”. “Just-in-time-information” could only partly motivate learner. Some of them were described as “confusing” and “overload”. Just as some “just-in-time-information”, “part-task practice” was not perceived as a-motivating element, but as “monotonous” and “boring without any additional value for learning”.

V. Discussion

Results indicate that the “VR-painting shop”, designed according to 4C/ID model [1], as a training tool for aspirant vehicle painters offers advantages for learners’ motivation. Motivation in VR learning environments has not yet been investigated sufficiently. Therefore, the pilot study points out the importance of learners’ motivation within the learning process. Investigating which aspects of “VR-painting shop” are less or more motivating, was somewhat difficult. Concluding, a virtual trainer and additional support in different presentation forms were perceived as highly motivating, whereas other instructional principles seem to fail to promote motivation. However, it should be noted that the first prototypes of the “VR-painting shop” were tested. Unsuccessful attempts to implement instructional principles could be the reason for missing motivational effects, too. Further research is needed to examine which aspects of a VR learning environment promote motivation to utilize benefits of a high learning motivation as high frustration tolerance or high willingness to learn [21], [24]. Therefore, a larger sample, a more sophisticated experimental design with control groups as well as various VR learning environments in different training settings are necessary. Additionally, comparisons between inexperienced and experienced learners as well as long-term studies are needed to differentiate between initial situational interest triggered by a new immersive medium (“novelty effect”) [36] and long-lasting motivation caused by appropriate instructional methods.

Taken together, VR offers a very high potential in education by making learning more motivating and engaging [37]-[39]. Following up on this research, this pilot study has two major contributions: First, it indicates that training in VR in vocational education for aspirant vehicle painters is highly motivating. Second, some elements of the 4C/ID model [1] seem to be suitable to create motivational “learning tasks”, especially the „supportive information” and the virtual trainer. In the future, we plan to conduct more research projects with more advanced study designs (e.g., enhanced training applications, a larger sample, long-term effects) to obtain these motivational benefits to support meaningful learning.

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