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Adapting Virtual Reality Training Applications by Dynamically Adjusting Visual Aspects

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ABSTRACT

The present work addresses the question how to design a Virtual Reality (VR) training application for a class of search and navigation tasks that dynamically adapts to users by adjusting visual aspects for visual guidance. We present a theoretical concept that dynamically adjusts visual aspects (lighting, colour) in virtual environments (VE) based on a combination of measuring user behaviour (head position, head orientation) and training performance (training time, error rate). The concept is build on derived requirements for a VR application that trains search and navigation tasks and a combination of previous approaches to meet them. A proof-of-concept (PoC) application was implemented, training order picking of parcels in a warehouse. Though the presented concept is sound as it is based on previous research, future work should conduct user studies to validate the concept with quantitative data.

Keywords

Virtual Reality Training, Adaptive Training, Visual Guidance, Human-Computer-Interaction

1 INTRODUCTION

Trainees' needs naturally differ from each other based on different knowledge, skills, demographic, socio-cultural background and learning rates [SZ12; Get84]. Static and predefined trainings are potentially too easy resulting in boredom, or too difficult resulting in anxiety and bad performance [ZA20]. Both affect training negatively [Pek+10; YLC18; Cha+08]. Adaptive training approaches counter these problems and enable more efficient training [Kel69; SZ12].

Finding the right balance between the difficulty of training tasks and skills of trainees has historically been the responsibility of human teachers and tutors [PL04]. Much research has been done to replicate the benefits of human's adaptive teaching capabilities in automatic, computer-based adaptive training [Lan+12].

One way to adapt training difficulty is by providing targeted assistance in form of visual guidance [Van13; GM20]. The extent of this targeted assistance is subsequently referred to as the level of assistance (LOA). Literature provides different approaches by adding visual indicators (e.g. arrows [Gru+18a; Lin+17], attention tunnels [Bio+07; SK08] halos and wedges [Gru+18a]) or changing visual aspects of a VE (e.g. lighting [RH18], blurring [ST13; HKS16]).

VR seems particularly suitable for adaptive training approaches and visual guidance for two reasons. First, modern Head Mounted Displays (HMD) are often equipped with a range of different sensors measuring data serving as a potential basis for adaptations [Nar+21]. Second, trainees are able to move and look around freely in a VE that is completely customisable.

The present work addresses the question how to design a VR training application for a class of search and navigation tasks that dynamically adapts to users by adjusting visual aspects of the VE for visual guidance.

Although literature examined a wide range of approaches for visual guidance, there is currently no combined approach for an adaptive VR training application that dynamically adjusts visual aspects (lighting, colour) in VE based on a mix of measuring user behaviour (head position, head orientation) and training performance (training time, error rate).

The class of search and navigation tasks is described in Section 2.1. Requirements for designing a respective theoretical concept are derived in Section 2.2. We review literature for relevant approaches which fulfil at least parts of the derived requirements in Section 3. We combined relevant previous approaches in an overarching theoretically sound concept, presented in Section 4. A respective PoC implementation is shown in Section 5. In Section 6 we critically reflect on the results and discuss limitations, followed by a conclusion and outlook on potential future work in Section 7.

2 REQUIREMENT ANALYSIS

In this Section, we describe the class of search and navigation tasks in Section 2.1. Requirements for designing a respective theoretical concept for a VR training application that dynamically adapts to users by adjusting visual aspects for visual guidance are presented in Section 2.2.

2.1 Training Scenario

We focus on training search and navigation task for single users, as these activities play central roles in different job profiles and offer a wide range of applications. In picker-to-parts-systems for example, which are the most common form of order picking, products need to be manually retrieved from the product storage by the order picker. Such job profiles are mainly low-skilled [OEC22; KLR07]. The training scenario essentially consists of two parts. First, search and navigate to a requested item which is located in a specific region of origin. Second, transporting the requested item to a specific destination.

2.2 Requirements

Based on the scenario, we derived five key requirements for a suitable training application for search and navigation tasks described below.

- ***Virtual Reality.*** VR is of special suitability due to the already in the Introduction described reasons. Furthermore, the application should be as widely applicable as possible
- ***Training Content.*** The goal is to find a certain item in a specific region of origin and transport it to a specific destination. Potential errors arise from selecting a wrong item or storing it at the wrong destination.
- ***Environment Interaction.*** The trainee requires possibilities for moving in the training environment and interact with the items to solve the training task.
- ***Adaptive Training.*** The training application requires adaption of the training difficulty to the trainee in the context of individual needs to enable efficient learning experiences [Kel69].
- ***Visual Guidance.*** The following requirements must be met to adapt training difficulty by using visual guidance for targeted assistance.
  - ***Draw Trainee's Attention***
    Able to attract learner's attention.
  - ***Dynamically Adaptable at Runtime***
    Able to adjust visual aspects in the VE dynamically at runtime without recognisable delay.
  - ***Adjustable in Different Level of Assistance***
    Visualisation of even small differences in the LOA.

3 RELATED WORK

In Section 3.1 we describe adaptive training approaches and address the key components of such approaches in the context of VR training. In Section 3.2, we reflect on previous approaches of visual guidance in VR training.

3.1 Adaptive Virtual Reality Training

There are various definitions of adaptive learning (see, e.g. Landsberg et al. [Lan+12]). The overall goal is to "meet the needs of individualized learners" [Vog+16]. We follow the definition of Kelley [Kel69] of a "training in which the problem, the stimulus, or the task is varied as a function of how well the trainee performs".

The advantages of adaptive training are justified by learning theories from the field of psychology (e.g. cognitive load theory [Swe88], Yerkes-Dodson law [YD+08], flow theory [Csi75]).

An adaptive training is a closed-loop feedback system consisting of three key components (see Figure 1) [Kel69]. Although only a small number of adaptive VR training approaches have been analysed in terms of their effectiveness, most of them have shown positive correlations [VGD16; ZA20].

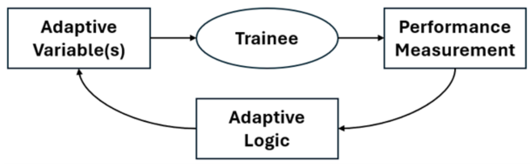


Figure 1. Illustration of an adaptive training cycle according to Kelley [Kel69].

In the following, we address the three key components of adaptive training approaches in the context of VR.

- *Adaptive Variable(s).* One or more adjustable variables that influence the user and their performance [Kel69]. There is a wide range of potential adaptive variables (see e.g. [ZA20; Lan+12]). With regard to the focus of the present work, we concentrate on attention guidance. Here, an overview of previous approaches can be found in Rothe et al. [RBH19]. While most approaches follow visual guidance, others follow haptic guidance [KR17; Cha+18], auditive guidance [Mar+19], guidance by forced rotation of the user's virtual body [Nie+16] or guidance of the physical body [Gug+16].
- *Performance Measurement.* Measurement data as the basis for determining the necessary LOA [Kel69]. Potential metrics can be task-related (e.g. performance during a training), related to physiological measurements (e.g. heart rate), kinematics (e.g. range of motion) [Lan+12; ZA20], the measurement of trainees skills, affective states,

and additional indicators such as personality traits or learning styles [SZ12].

- *Adaptive Logic.* Computation of the LOA based on the *Performance Measurement* to derive the corresponding adjustment of the *Adaptive Variable(s)* [Kel69]. The collected data can be processed with techniques such as machine learning, optimisation strategies, rule-based systems, or conditional statements [ZA20]. Multiple approaches have been identified with adaptions prior to the training, during the training or, combined in a two-step approach, with adaptions prior and during the training [PL04; Vog+16; Lan+12]. Continuous assistance during a training leads to over-dependence, which results in lower training performance without assistance [TGH15].

3.2 Visual Guidance in Virtual Reality

Visual guidance approaches often add visual indicators to the user's field of view like specific pointers towards relevant areas of the VE. These have been investigated in form of arrows [Gru+18b] [Lin+17], attention tunnels [Bio+07; SK08] or halos and wedges [Gru+18a]. Other indicators visualize the location of relevant areas in relation to the user's current position and orientation [Bor+18]. According to Bork et al. [Bor+18], these approaches can have the problem of adding visual clutter and occupying huge amounts of screen space, which is a limited commodity in current HMDs.

Other approaches of visual guidance suggest changing visual aspects of the VE to guide the user's attention. Here, previous literature examined the use of lighting [RH18], the blurring of irrelevant sections of the VE [ST13] [HKS16], slight visual changes to the VE based on saliency maps [MFS10] [Vea+11] or modulations of luminance at the edge of the user's vision [Bai+09] [Gro+17]. According to El-Nasr et al. [El-+09] visual guidance in form of lighting can reduce the time for a user to search and find enemies in a respective game [El-+09]. Boggus and Crawfis [BC10] show that visual guidance in form of lighting can reduce the time to navigate within the VE.

The previous literature provides a wide range of approaches for visual guidance in VR, even in the context of adjusting visual aspects. Although a number of approaches provide potential answers to parts of our derived requirements, there is currently no combined approach fulfilling them all. In the next section we therefore present an appropriate approach.

4 CONCEPT

In this Section we present a concept for a VR training application for a class of search and navigation tasks that dynamically adapts to users by adjusting visual aspects (lighting, colour) in VE for visual guidance. We base the adjustments on a mix of measuring user behaviour (head position, head orientation) and training performance (training time, error rate).

We build the concept on the derived requirements from Section 2.2 which we meet with a mix of previous approaches from literature from Section 3. We therefore consider the concept as theoretically sound.

To meet the requirements of ***Virtual Reality*** our concept is designed for HMDs with head motion tracking in six degrees of freedom, a common capability [Dör+19].

To meet the requirements of ***Adaptive Training***, our concept consist of three key components following Kelley [Kel69].

In Section 4.1 we describe the concept meeting the requirements for a class of training of search and navigation tasks. Regarding the three key components, the adaptive variables are described in Section 4.2, the performance measurements are described in Section 4.3 and the adaptive logic is described in Section 4.4. The concept covers all five requirements which we will explain in detail.

4.1 Training Search and Navigation

To meet the requirement of ***Training Content***, our concept suggests the following content for training search an navigation tasks.

- **Item Requests**
  Generation and displaying of item requests.
- **Specific Destination(s)**
  Specific destination(s) for selected items.
- **Region of Origin**
  Different regions of origin with various items.
- **Display Results**
  Discerning correct and wrong delivered items.

To meet the requirement of ***Environment Interaction***, our concept suggests the following interaction and movement possibilities for the training of search an navigation tasks.

- **Locomotion**
  Locomotion by transferring physical movements from the real world to the VE and by teleportation.
- **Object Manipulation**
  Possibility to interact with designated items.

4.2 Adjustable Visual Aspects

We suggest and assume the use of common game engines (e.g. Unity [22b], Unreal Engine [22c]) for the design of VEs. To meet the requirements of ***Visual Guidance***, our concept suggests the adjustment of the following two visual aspects as adaptive variables.

- **Object Colour**
- **Lighting Intensity**

The requirement to ***Draw Trainee's Attention*** is met, as colour has been shown to attract direct attention [WH17], and lighting has been shown to draw attention to the area around the light source [Vin+09]. The primary colours red, green and blue are potential candidates as colours stand out more clearly that are closer to being a primary colour [BK17].

The intensity of the attention guiding effect depends on the degree to which the region of origin is visually distinguishable from the non-region of origin [WH17] [DH89].

The requirement of ***Dynamically Adaptable at Runtime*** is met by using the functionalities of common game engines enabling to adjust the material properties and thus the object colour, and lighting at runtime.

The requirement of ***Adjustable in Different Level of Assistance*** is met, by using common game engines where object colour and lighting intensity are stored in form of floating point values and therefore finely adjust- and visualisable.

4.3 Behaviour and Performance

Our concept suggests to distinguish between measuring the behaviour (*Training Behaviour*) and the performance of the trainee (*Training Performance*) with two metrics each.

Training Behaviour is measured by the two metrics:

- **Distance to the Task Goal.** This metric measures the length of a straight line drawn from the trainee's head position to the region of origin. It indicates how close the trainee is to physically reaching the region of origin.
- **Angular Distance to the Task Goal.** This metric measures the angle between the trainee's current head orientation and the necessary orientation to face the region of origin. It indicates how close the trainee is to visually finding the region of origin.

Training Performance is measured by the two metrics:

- **Training Time** This metric measures the time it takes to complete a training session. We suggest to start measuring when a training session begins until all objectives of the training task have been achieved. A shorter task execution time indicates a higher level of competence.
- **Number of Errors** This metric measures the number of errors made during a training session. A lower amount of errors indicates a higher level of competence.

4.4 Adaptive Logic

The adaptive logic contains two steps. First, *Determining the LOA* based on the collected data from *Behaviour and Performance* which will be described in Section 4.4.1. Second, *Adjusting the Visual Aspects* according to the determined LOA which will be described in Section 4.4.2.

4.4.1 Determining the Level of Assistance

Two values each for *Behaviour and Performance* (as described in Section 4.3) determine the LOA.

First, the *Training Behaviour* values define the **Needed LOA**, which in turn quantifies the current need for assistance during a *Training Round*. This LOA is adjusted at runtime.

Second, the **Maximum LOA** is based on *Training Performance*. The upper bound of assistance, hence Maximum LOA, is intended to prevent the adaptive logic from providing more assistance than justified by the trainee's performance. This limit is adjusted after each *Training Round*.

Both determined LOAs are in the range from 0 to 1, with the respective range of no assistance to full assistance. As the circumstances of training scenarios can differ, it is essential to define the two boundary values for every scenario. Whether values are considered high or low must therefore be defined on an individual basis.

The concept follows Landsberg et al. [Lan+12] with a two-step approach, containing adaptions prior and during the training. Hence, the training consist of at least two rounds. In the first training round, the Maximum LOA is initially set to 1.

The following steps are subsequently executed to determine the LOA:

1. **Calculating the Needed LOA**
   We assume that the further away the trainee is from reaching the task goal, measured by the *Training Behaviour* values, the greater is the need for assistance. The *Needed LOA* is calculated by averaging the normalised values of *Distance to the Task Goal* and *Angular Distance to the Task Goal*.

2. **Adjusting the Maximum LOA**

   The *Maximum LOA* is adapted to the trainee's changing abilities. The adjustments are based on the relative change in the *Training Performance*.

   As performance increases, the *Maximum LOA* is reduced to avoid boredom. If performance decreases, the *Maximum LOA* is increased to avoid anxiety. Adjustments are made after each training round and correspond to the relative change in training performance.

   The relative change is determined by subtracting the prior training performance from the current training performance.

4.4.2 Adjusting the Visual Aspects

After deriving the LOA calculated by the adaptive logic, the visual aspects are respectively adjusted. We subsequently describe both adjustable visual aspects in Section 4.2.

Lighting Intensity. Two conditions must be met when using light intensity as an adjustable visual aspect. First, the VE must be illuminated by different, separately adjustable light sources, with at least one light source per potential region of origin. Secondly, the potential regions of origin must be illuminated as uniformly as possible at the beginning to ensure changes in light intensity are perceivable to guide trainee's attention.

Adjusting light intensity according to the LOA in form of visually perceptible differences involves reducing the light intensity of the light sources that illuminate the non-regions of origin while increasing the light intensity of the light source that illuminates the region of origin.

Object Colour. To use object colour as an adjustable visual aspect, each possible region of origin must contain largely similar items with similar surface colours. This is necessary to avoid large visual differences between the region of origin and the non-region of origin in the starting point.

To guide trainees' attention, the surface colour of one or more selected items in the region of origin is highlighted according to the LOA, while the surface colour of the items outside the region of origin remain the same.

5 IMPLEMENTATION

This Section describes a PoC implementation of the previously presented concept in form of a VR application that trains search and navigation tasks by training order picking of parcels in a warehouse. The PoC covers all elements of the concept, which we will explain in detail.

The VR training application is presented in Section 5.1. Instead of repeating the already in Section 4 described three key components of an adaptive approach, we go into relevant details of the application of the concept. The boundary values of measuring behaviour and performance are defined in Section 5.2.

In Section 5.3 we present exemplary visual guidance in form of adjusting lighting intensity and colour for three different LOA each.

In Section 5.4 we present a system overview regarding the used hard- and software.

5.1 Training Order Picking of Parcels

Down below, the training task, VE and environment interaction are described.

5.1.1 Training Task

We choose order picking in a warehouse as the training task. Order picking refers to the process of "retrieving products from storage in response to a specific customer request" **(Item request)** and transporting it to a specific destination **(Specific Destination)**.

Four regions of the VE are defined as possible regions of origin, one for each group of three shelves **(Region of Origin)**. A display shows weather the correct parcel was delivered **(Display Results)**. See Figure 3 for respective illustrations. As the position of the destination is defined and known, changing visual aspects are intended to assist in finding the parcels in the regions of origin.

Therefore, the PoC contains all four elements for content of training search and navigation tasks from our concept in Section 4.1.

5.1.2 Environment Interaction

There are two possibilities for locomotion. First, participants can move in the real world, with their movements being replicated in the VE. Second, participants can teleport within the VE. By pressing a button on the controller, the possible movement is displayed. When the button is released, the trainee is teleported there **(Locomotion)**.

Interactions with parcels are possible by pressing the grip button on the controller as soon as a virtual hand crosses a parcel. After pressing the grip button, the parcel is fixed in the position of the learner's hand until the button is released again. Each interaction is defined for the left and right controller, enabling the trainee to perform each interaction with both hands. The self-representation is limited to the virtual representation of the hands **(Object Manipulation)**. See Figure 2 for respective illustrations.

The PoC contains both elements of interaction and movement possibilities for training search and navigation tasks from our concept in Section 4.1.

Figure 2. Illustration of a potential teleportation (left) and the interaction with a parcel by transporting it to the destination (right) [Lei21]

5.1.3 Virtual Environment

We implemented a simple designed warehouse for the training environment. It consists of a square room, with four groups of three shelves each attached to the walls of the rear half of the room as item storage. Each shelf contains three spaces for storing items. Each storage location is randomly filled with a cardboard box of different sizes, which serves as the stored items. To enable textual representations of the product locations for customer enquiries, each storage location is labelled alphanumerically with a letter followed by a number. The letter clearly identifies the shelf on which the product is located. The number indicates where the product is located on this shelf. On the other side of the room, a table with a sufficiently large crate has been set up, which is intended as the destination for the requested products. A large monitor on the wall behind the table enables the visual display of customer requests and other relevant information. See Figure 3 for respective illustrations.

Figure 3. Illustration of the front side (left) and back side of the warehouse (right) [Lei21]

5.2 Setting the Boundary Values

By measuring *Training Behaviour* and *Training Performance*, the PoC contains all suggested measurements from our concept in Section 4.3.

As described in Section 4.4, both values from *Behaviour and Performance* are mapped between 0 and 1 and need to be defined individually for a training scenario. For the PoC we defined the following, based on performance observations during the development.

Regarding *Training Behaviour*, for the **Distance to the Task Goal** a small distance is defined as 0.5 meters, while a large distance is defined as 10 meters (e.g. wall on the other side of the room).

For the **Angular Distance to the Task Goal.** a small angular distance is defined as 0°, since at this angle, the trainee's head is oriented right at the region of origin. The definition of a large angular distance is closely related to the used HMD, respectively the field of view.

In Section 5.4, we go into more detail about the used hard- and software. However, as the used HMD (Oculus Rift S) has been measured with 94.25° diagonally [MMR20] any object further than 47.125° from the centre, won't be visible for the trainee anymore. We therefore defined 40° as a large angular distance.

Regarding *Training Performance*, for the **Training Time** a sufficient performance is defined as ≤ 5 seconds and an insufficient is defined as ≥ 15 seconds per requested parcel. For the **Number of Errors** a sufficient performance is defined as ≤ 1 error and an insufficient is defined as ≥ 1 error per requested parcel.

5.3 Adjusting Visual Aspects

In this Section we present the adjustable visual aspects *Lighting Intensity* as well as *Object Colour*. The PoC contains all relevant elements for both visual aspects from our concept in Section 4.2 as well as the adaptive logic by respective adjustments as described in Section 4.4.

5.3.1 Adjusting Colour

In this section we present exemplary visual guidance in form of adjusting colour for three different LOA. See Figure 4 for respective illustrations.

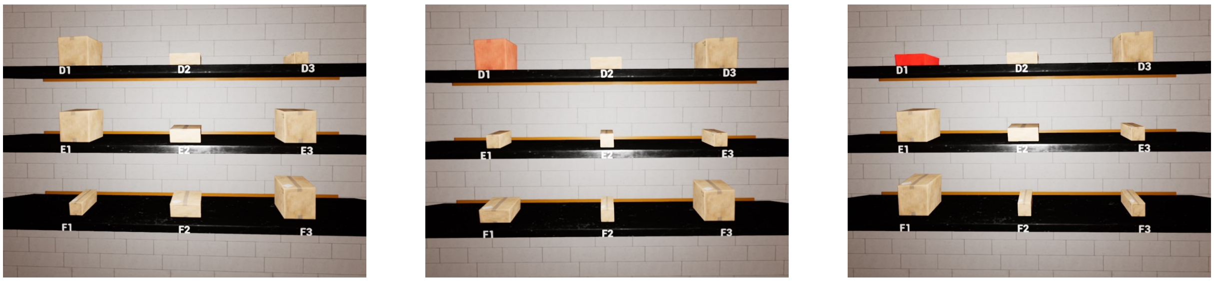
For the LOA of 0, the surface colour for each object remains at its base colour. It is provided by a texture image to make it look like a cardboard box. Since all products use the same texture image, there is no visual difference between the region of origin and non-regions of origin.

With an LOA of 1, the surface colour of the selected object is set to the target colour. Thus, the region of origin is clearly distinguishable.

For LOAs between 0 and 1, the surface colour of the region of origin is interpolated accordingly. To prevent the target colour from differing too much from the base colour even at a small interpolation, we use red as the target colour. This primary colour comes closest to the light brown basic colour of the base colour. In addition, red is often used as a warning colour, which can attract a lot of attention if required.

5.3.2 Adjusting Lighting Intensity

In this section we present exemplary visual guidance in form of adjusting lighting intensity for three different LOA. See Figure 5 for respective illustrations.



(a) Level of Assistance: 0 **(b) Level of Assistance: 0.5** **(c) Level of Assistance: 1**

Figure 4. Examples of assistance by adaptation of colour [Lei21]

In accordance with the requirements for the use of light intensity described in Section 4.4.2, each potential region of origin (shelf group) has an adaptive light source. The attenuation radius (radius in which the light source acts on the VE) is limited to ensure that, in case of a certain LOA, the adaptive light sources only illuminate the assigned shelf group, while the other adaptive light sources diminish. Basic lighting is provided for the other areas of the VE that are not illuminated by adaptive light sources. Light intensity is measured in candela [NPL24].

The intensity for basic lighting is set to 2.5 candela. For the LOA of 0, the lighting intensity is set to basic lighting for all potential regions of origin. With a LOA of 1, lighting intensity is set to 5 candela for the specific region of origin and 0 candela for all other non-regions of origin. For LOAs between 0 and 1, the surface colour of the region of origin and non-regions of origin are interpolated accordingly.

5.4 System Overview

We used the Oculus Rift S an HMD offering 6 degrees of freedom and inside-out tracking from five cameras mounted on the outside of the HMD. It has a resolution of 1280x1440 pixels per eye and speakers mounted in the headband above the user's ears and needs to be connected to a desktop PC. The HMD is controlled by two (right and left) *Oculus Touch controllers* of the second generation as input devices [22a]. For the implementation we used *Unreal Engine 4.27*, a suite of creation tools for the purposes of game development and architectural visualisations [22c] and the programming language *C++*.

6 RESULTS AND DISCUSSION

In this Section, we present and discuss the results.

6.1 Results

The major contribution of this work is the presented theoretical concept. To create the concept for the selected class of training applications, we first derived five core requirements. We then conducted a literature review to examine previous approaches to be able to fulfil at least partial requirements.

Although literature examined a wide range of approaches for visual guidance, there is currently no combined approach for an adaptive VR training application that dynamically adjusts visual aspects (lighting, colour) in VE based on a mix of measuring user behaviour (head position, head orientation) and training performance (training time, error rate).

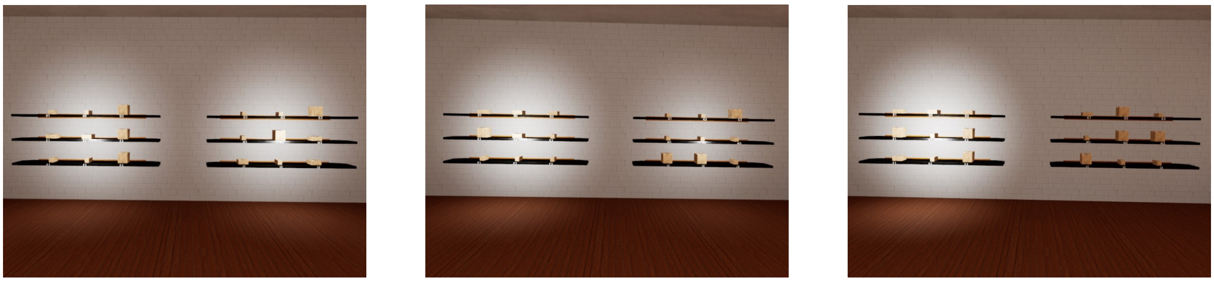
The presented concept meets all five key requirements. As it basically consists of a combination of previous approaches, we consider it to be theoretically sound.

An additional contribution can be seen in the creation of the PoC implementation.

6.2 Discussion

Looking at the presented results, we have to mention some limitations. Above all, the theoretical soundness we assume is based on the validity of the approaches we combined from literature. Although these are certainly valid when considered individually, their validity in combination is subject to an appropriate validation, e.g. by user studies. Here, the presented PoC implementation emphasises its relevance for future research.

Furthermore, the effect of the presented concept on training effectivity can be influenced by several factors. The first factor concerns the determination of the correct LOA. Based on simple measurements and algorithms, there is a risk that the adaptation to the trainee's needs are inadequate. The second factor concerns the effect of the proposed adjustable visual aspects. It is reasonable to assume that these have different effects on the guidance of visual attention. Corresponding evaluations must clarify the respective influence and be taken into account accordingly in the extent of the adjustments. The third factor concerns possible technological challenges in form of sufficient computing power, e.g. to prevent motion sickness for the user. In the context of near-real-time adjustments of visual aspects, this requires the maintenance of high frame rates, which requires fast and efficient graphical



(a) Level of Assistance: 0 (b) Level of Assistance: 0.5 (c) Level of Assistance: 1

Figure 5. Examples of assistance by adaptation of lighting intensity [Lei21]

rendering. The needed performance in turn varies with the selected adjustable visual aspects.

We also see a potential limitation regarding object colour as an adjustable visual aspect, since all objects must have a comparable base colour to enable visual distinguishability according to the LOA.

7 CONCLUSION AND OUTLOOK

In this section, we present a conclusion and outlook on future work.

7.1 Conclusion

This paper investigates how to design a VR training application for a class of search and navigation tasks that dynamically adapts to users by adjusting visual aspects for visual guidance. Building on a requirement analysis and literature review, a theoretically sound concept and a respective PoC implementation is presented.

As there is no comparable approach in previous literature, the approach contains a certain independence and novelty. As the theoretical soundness however, is derived from the fact that the approach basically consists of a combination of previous approaches, further validation is necessary (e.g. by user studies).

Since, in addition to the theoretical concept, a corresponding PoC implementation is presented, important prerequisites as well as concrete suggestions for promising future research are given.

7.2 Outlook

We see two approaches for future work. First, since the presented concept is build on previous approaches from literature, we consider the concept as theoretically sound. However, we propose to validate it with quantitative data by conducting user studies.

Second, we propose to examine the integration of physiological measurement data as performance measurement. Modern HMDs (e.g. Varjo [Var24]) are often equipped with a variety of sensors on board (e.g. eye tracking). Physiological measurement data contain information about the physical, emotional and cognitive states of the user and therefore offer the potential to adapt training to the user [HL21; Mar+20].

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