Ego OR Exo:
Comparing Visual Perspectives on Guidance Visualisations for Motor Learning

Masterarbeit

vorgelegt von

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Abstract

Motor Learning in Mixed Reality prooved to be good. But view reseach in the influence of the perspective on guidance visualisation. This work proposes a study to investigate this. Task is handling physical load. will enable designers of MR ML systems to base their work on on empirical data.

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1 Introduction

The acquisition of movements is a crucial part of human development. Learning movements empowers to be more efficient, faster and more exact. The capability of enhanced movements enables the learner to survive from the very beginning. The process of learning movements is called Motor Learning. Nowadays, Motor Learning is still crucial. Especially for tasks like sports, arts or the ergonomic handling of physical load.
Most movements we learn by voyeurism and mimicking: watching and trying it out by yourself. Mastering a movement is performed best with an experienced teacher. A teacher is hardly replaceable because of immediate visual, audible and haptic feedback on a performed movement. However, if a teacher is not available, for example, based on the location or economic reasons, other sources can be used to learn movements. For example, YouTube[1], TikTok[2], and other video platforms have become a great source for learning videos with a wide range of purposes. The downside of videos is the two dimensional (2D) experience of a three dimensional (3D) movement. Mixed Reality (MR) can provide this experience in 3D. Furthermore, MR can provide feedback on the performed movement and has the ability for interactions with the virtual guidance visualisation. MR already proved to be a suitable environment for Motor Learning for tasks like dancing [1–5], sports [6, 7], Rehabilitation [8–12], arts [13–20] and others [21, 22].
In the real world, where the student and teacher are real persons, the student sees the teacher, for example, in front of himself/herself. This perspective is called the exo-centric visual perspective. Nevertheless, if we move from the real world to the virtual world of MR, we are no longer restricted to the exo-centric visual perspective. The teacher can be rendered inside the student's body, allowing the student to see the teacher from an ego-centric perspective. The change from the exo-centric to the ego-centric visual perspective potentially influences Motor Learning, shown by previous research; for example, AR-Arm [13] lets the learner experience the movements from an ego-centric perspective. YouMove [1] teaches dance from an exo-centric perspective. OneBody [19], Light Guide [22], MR Dance Trainer [5], Free Throw Simulator [6], Training Physical skills [7], Sleeve AR [11] and Thai Chi Trainer [20] use both visual perspectives. However, only OneBody, LightGuide and TaiChi Trainer found a difference between the visual perspectives. Furthermore, none of these works investigated how the visual perspective influences the performance of the learner. Another topic where MR could be a valuable helper is the ergonomic conduction of movements while handling physical load [23, 24]. Handling physical load in the correct ergonomic conduct in working routines can prevent injuries in everyday life. However, a kinaesthetics teacher is not always accessible, for example, for economic reasons. The influence of the visual perspective on a virtual guidance visualisation teaching the handling of physical load in mixed reality is sparsely investigated todo: is there a source?. Especially, transitional movements like walking in the ego-centric perspective is left out. The lack of research in the influence of the visual perspective on a virtual guidance visualisation, especially for handling physical loads, shows the necessity of investigations on:

RQ1: How does the visual perspective on a virtual guidance visualisation influence Motor Learning in Virtual Reality environments?

To answer this main research question RQ1, several aspects have to be taken into account: accuracy of movements, transfer of information of how to move, the visual focus of the learner and last but not least, the personal preference of the learner. Therefore, to answer the main research question RQ1, it is necessary to answer the following sub-research questions:

[1] https://www.youtube.com/, accessed 17.2.2021
[2] https://www.tiktok.com/, accessed 17.2.2021

RQ1.1 How does the visual perspective on a virtual guidance visualisation influence movements' accuracy?

RQ1.1.1 How does the visual perspective on a virtual guidance visualisation influence movements' accuracy of the own body?

RQ1.1.2 How does the visual perspective on a virtual guidance visualisation influence the accuracy of handling physical load?

RQ1.1.3 How does the visual perspective on a virtual guidance visualisation influence sub-tasks' accuracy?

RQ1.2 Does the visual perspective on a virtual guidance visualisation influence the transfer of ergonomic principles?

RQ1.3 How does the visual perspective on a virtual guidance visualisation influence the learner's visual focus?

RQ1.4 What is the subjective personal preference of the learner for the visual perspectives?

A detailed discussion of the research questions can be found in 3.2.
The answers to these research questions will enable designers of VR Motor Learning training systems to choose a suitable visual perspective on an empirical basis.

1.1 Outline

This work proposes a study design to answer the research question. To design this study on a solid basis, the theoretical foundations a laid in chapter 2 with a closer look on Motor Learning (section 2.2), visual perspectives (section 2.3) and Mixed Reality (section 2.1). These sections result in the scope and parameters of the study design. Section 2.5 investigates previous works and illustrates the conceptual delimitation of this work from what has already been investigated. Chapter 2 concludes with a research contribution statement, clarifying the Empirical Contribution and Artifact Contribution of this work.
For the proposed study, a system had to be designed to produce data to answer the research questions. This system is called E(x|g)oṪhe design and and implementation is described in section 3.1 followed by the design of the study itself in section 3.2.
E(x|g)o and the study design have been evaluated in a pilot study. The results of the evaluation are depicted in chapter 4. Furthermore, this chapter suggests improvements in the study design in section 5.2. This work concludes in chapter 5 with an outlook on how E(x|g)o can be enhanced and expanded as well as used for further investigations.

long long label asdad asfiojh aojgf oijgoias gjoasig

2 Motor Learning in Virtual Reality

The aquisition and improvement of movements is called motor learning [25].

2.1 Mixed Reality

Milgram and Kishinho [26] describe Mixed Reality for visual displays on a continuum (see seminar thesis chapter 2.3). In Virtual Reality the environment is blocked completely while in Augmented Reality the environment is visible and augmented with digital elements. During Motor Learning the visual perception of the own body is desireable, though the approach of augmenting the real-world body with a virtual guidance visualisation is promising. But todays AR-technology provide a small field of view. A solution to this could be the video see-through technology, but this is also limited by latency and distrotion.
The perception of the own body can also be achieved by rendering the body of the learner and though can be established in VR. This solution is applied in the proposed study design and the study takes place in Virtual Reality.

2.2 Motor Learning

Motor Learning is achieved through instruction, trying, imitation or a combination of them. The process of Motor Learning can be divided into three parts: cognitive stage, assosiative stage and autonomous stage. In the cognitive stage, training methods are most efficient and the performance gain ist the highest among the stages [25]. Tasks that belong to this stage are thereby best suited for a study. A detailed description of the stages can be found in the preceeding seminar thesis.
Movements can be calassified by two means: by the particular movements and based on the perceptual attributes. Based on the particular movements, the classification is described by a continuum, compare figure 2.1. On the extremes of the continuum are discrete movements and continuous movements. Between these extremes, serial movements are located. For a detailed description please refere to seminar thesis chapter 2.2. Discrete movements are too short for an evaluation. Continuous movements do not have an recognisable beginning and thereby they are not suitable for the study in question either. Serial movements are basically chained discrete movements with a recognisable beginning and end. This allows to determine a task decomposition compare section 2.4 and a evaluation of particular tasks. Discrete movements are widely used for reseach in Motor Learning, for example [16, 17, 22], therefore, the study task design is based on discrete movements.
The classification based on the perceptual attributes is also represented by an continuum and includes the environment the movement is performed compare figure 2.2. At the extremes of the continuum open skills and closed skills are located. For closed skills, the environment is predictable while in open skills the environment is not predictable. The study aims to analyse the learners performance of following a movement and not how the learner can adapt to environmental changes, the task for this study must be located on the left hand side of the continuum: closed skills.

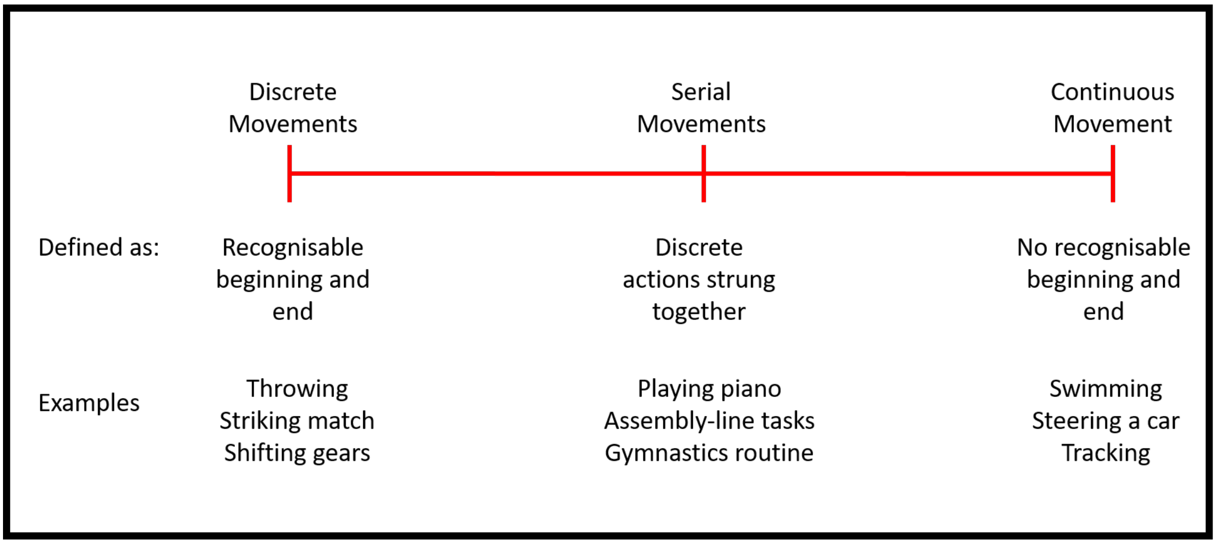

Figure 2.1: Movement classification 1 [25]

2.2.1 Measurements for Motor Learning

2.3 Visual Perspectives

Wang and Milgram [27] describe visual perspectives by the centricity continuum 2.3. On the left extreme on the continuum, the ego-centric visual perspective is located, on the right extreme the exo-centric visual perspective can be found, while the middle part represents tethered visual perspectives. By moving from the left to the right the so called tethering distance increases. The tethering distance describe the distance of the anchor point of the eyes to the object to control. In this work the object to control is the learners avatar guidance visualisation. Furthermore, Wang and Milgram distinguish tethered visual perspective in dynamic and rigid, a detailed description is given in the seminar thesis chapter 2.1. Given a scenario where one learner mimics the movement of one teacher, five different visual perspectives are possible:

- Ego-centric: the avatar of the teacher is located inside the body of the avatar of the learner; the learner sees the guidance visualisation inside the own body, compare figure 2.4 top left.
- Exo-centric: the avatar of the guidance visualisation is located outside of the avatar of the learner; the learner sees the guidance visualisation e.g. in front of him/her, compare figure 2.4 top right.
- Ego & exo-centric: the combination of ego-centric and exo-centric. The learner sees the guidance visualisation as well as inside and outside of the own body, compare figure 2.4 middle left.
- Augmented exo-centric: the guidance visualisation is located outside of the leraners avatar, additionally, a virtual copy of the student is located inside the exo-centric guidance visualisation, compare figure 2.4 middle right.
- Ego & augmented exo-centric: the combination of the ego-centric visual perspective and the augmented exo-centric visual perspective; the learner sees the guidance visualisation inside the own body, as well as

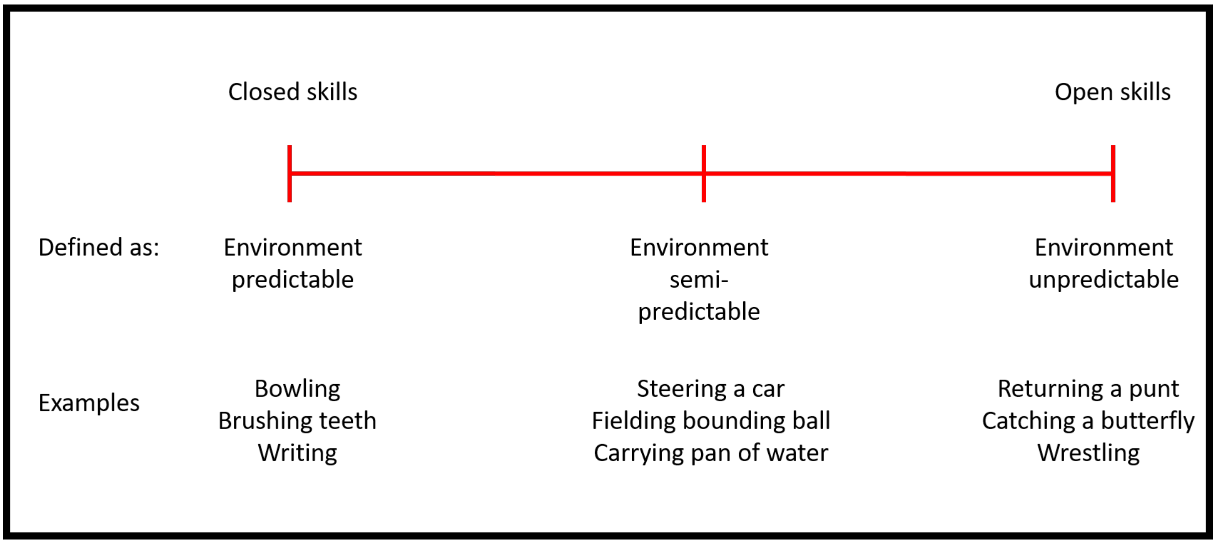

Figure 2.2: Movement classification 2 [25]

outside. Additionally, a virtual copy of the learner is located inside the exo-centric guidance visualisation, compare figure 2.4 bottom.

All visual perspectives are worth an investigation and a comparable study with all five visual perspectives is desirable. Though, to reduce complexity and the number of participants[1], this work will focus on three visual perspectives: ego-centric, augmented exo-centric and ego & augmented exocentric for the following reasons. In the ego-centric visual perspective, the learner sees the teacher inside the own body. Here, the learner can see the relation of the own body to the teachers body directly. In the exo-centric visual perspective this relation cannot be seen. Thereby, the position of the learner in relation to the guidance visualisation must be guessed. That, in turn, makes the application of the speed machanic which is necessary for ego-centric guidance - described in the next section - not possible. A mechanic that is used in all conditions but one could lead to biased data, compare table 2.1. The mechanic of multiple representations does not influence the validity of the study, because

Perspective	**Speed Mechanic**	**Multiple Representations**
Ego-centric	Yes	No
Exo-centric	No	Yes
Ego & Exo-centric	Yes	Yes
Augmented Exo-centric	Yes	Yes
Ego & Augmented Exo-centric	Yes	Yes

Table 2.1: mechanics comparison

the mechanic would solve an issue that does not exist in the ego-centric perspectives.
In the augmented exo-centric perspective, a virtual copy of the learner is located inside the exo-centric guid-

[1]Due to COVID-19 pandemic

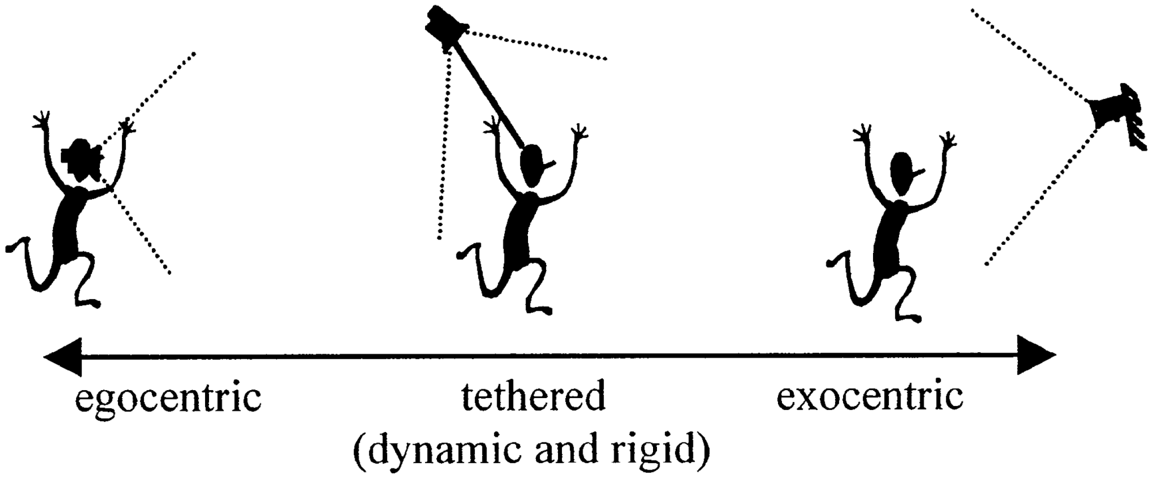

Figure 2.3: Centricity continuum by Wang and Milgram [27]

ance visualisation. The copy lets the learner see the relation of the own body to the guidance visualisation. Furthermore, augmenting the exo-centric guidance visualisation with the learner is applied and evaluated in related work [1, 20]. Because the speed machanic cannot be applied and the method of augmenting exo-centric guidance visualisation with a virtual copy of the learner, the augmented exo-centric perspective will be used in the proposed study. For simplicity reasons, the augmented exo-centric visual perspective will be further called exo-centric visual perspective.
The third visual perspective that will be used in the proposed study design is the combination of the ego-centric and exo-centric visual perspective: augmented exo-centric visual perspective, which will be further called ego & exo-centric visual perspective.

2.3.1 Mechanics for Motor Learning in Virtual Reality

For teaching movments in Virtual Reality, in the exo-centric visual perspective the following issue arises. The guidance visualisation can move out of the field of view of the learner by the movement itself. Szenario: the learner and the guidance visualisation stand side-by-side, the learner sees the guidance visualisation on the left of hin/her. The guidance visualisation now indicates a movement to turn by 90 degrees to the right. When the learner follow thsi movement, the guidance visualisation will be located behind the learner after the movement ended. A guidance visualisation standing behind the learner cannot be seen by the learner.
This issue is solved in existing work with either the restriction of movements [6, 16] or multiple representations of the guidance visualisation arround the learner [17, 20]. The restriction of movements has an strong influence in the task design and is therefore not desirable for the study proposed in this thesis, consequential for exo-centric visual perspectives multiple representations fo the guidance visualisations on strategic positions arround the learner are used.
In the ego-centric visual perspective, another issue araises during the teaching of transitional movements in space: walking. To understand this issue, two aspects have to be clear before. (1) The nature of an ego-centric guidance visualisation is to be located inside the learner at any time. (2) A guidance visualisation indicates movements by moving itself. If the guidance visualisatoin is about to indicate a movement away from the learner, the guidance visualisation is moving out of the students body. But a guidance visualisation that is outside of the learners body is no longer ego-centric.

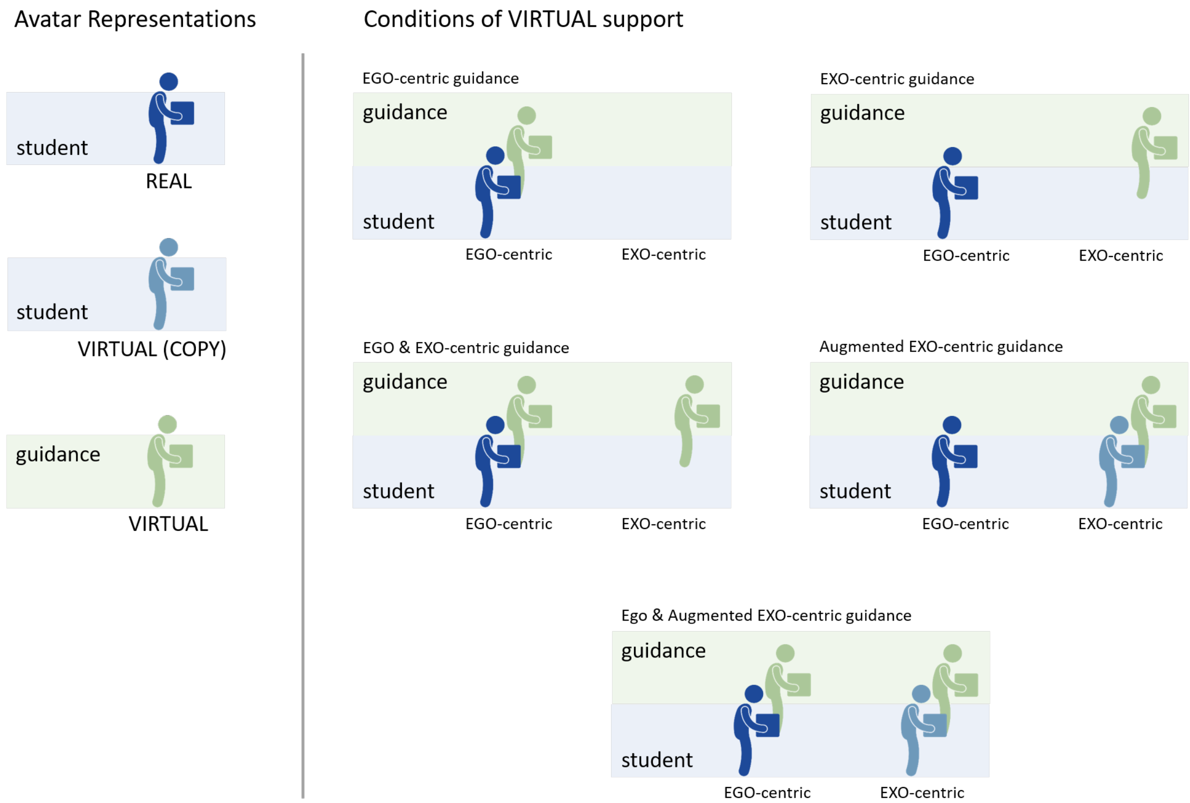

Figure 2.4: Possible perspectives with one real world student and one real world teacher.

A possible soltuion can give the centricity continuum by Wang and Milgram 2.3. Following the nature of the centricity continuum, the tethering distance can be increased by a small ammount and the visual perspective can still be classified as ego-centric. But now araises the question, of how far the tethering distance can be increased, with which the perspective still feels ego-centric, but the indication of the movement is considerable. For simplicity reasons, this distance is further called ego-centric tethering distance (ETD). To determine a reasonable ETD, a small formative study was conducted[2]. During this study, a non biased[3] person was asked to follow movements in the ego-centric visual perspective. The first movement was conducted with an ETD of 5cm. For the folowing movements the ETD was increased by 5cm each. The subjective assesment of the participant and my observations yielded best for an ETD between 15cm and 30cm. These two values are further called:

$$ETD_{min} = 15cm$$

$$ETD_{max} = 30cm$$

Based on ETD_{min} and ETD_{max} the speed mechanic is developed. The speed mechanic controls the speed of the playback of the guidance visualisation. At ETD_{min} the animation plays at normal speed, at ETD_{max} the guidance visualisation stops. Between ETD_{min} and ETD_{max} the animation speed of the guidance visualisation is linearly interpolated, compare figure 2.5. The speed mechanic was evaluated by one[4] person. The participant

[2]A larger study was not possible because of the COVID-19 pandemic
[3]The person had no prior knowledge about the system or motor learning.
[4]Different person than the initial. This person had no prior knowledge about the system or motor learning. Larger evaluation not possible because of COVID-19 pandemic.

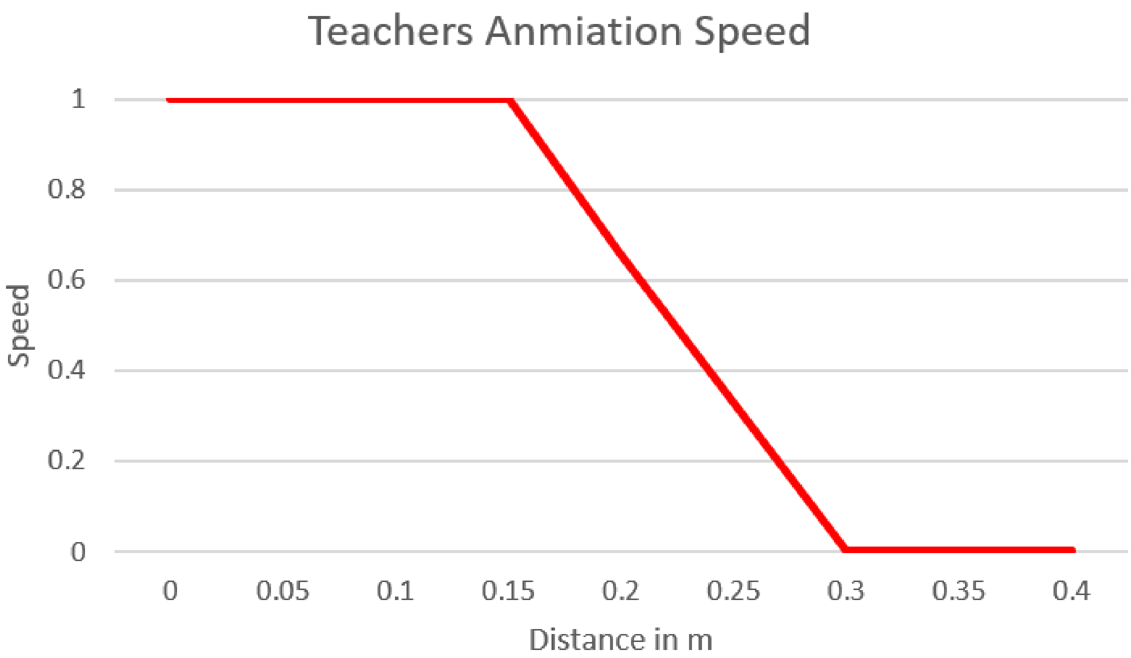

Figure 2.5: speed mechanic chart

followed the guidance visualisation in the ego-centric visual perspective. Observations showed that the participant could follow the movement at ease. The opinion of the participant about the speed mechanic was very positive.

2.4 Handling Physical Load

The handling of physical load is composed of five elemental tasks: lift, lower, push, pull and hold [28]. Additionally, there are non-elemental tasks like turning and sliding, ibid.. This work will use a study tasks that include the handling of physical load. Evidently, the task should consist of these elemental tasks. A tasks which consists out of the elemental tasks can be generalised to other tasks, to certain degree. To gain a strong data basis, multiple elemental tasks can be chained together (so called Unit-Combined-MMH ibid.). The task design for the proposed study founds on this basis and additionally should have a reference to real-world tasks. For the task, a simple box serves as physical load, compare chapter todo: 3.
The real world provides a variety tasks that include the handling of physical load. For example in a pacel transhipment point, wearhouse workers, grinders or people that work at test stands. They pic up physical load, carry, turn and pull it. To imitate such a task, additional artifacts were created to be used in the proposed study. A table for push and pull, that could be interpreted as a machine or sorting platform and a plate on the floor that could depict for example a scale. Between the table and the scale the box can be carried. The box can be lowered and lifted from and to the scale.
As described in chapter todo: 4, the legs during push and pull are in the same position if executed ergonomically. To gain variation, which is necessary to get insight how the learner can see the feet of the guidance visualisation, two non-elemental tasks were introduced: turn and fold. During this task the foot placement is different to push

and pull. With the sub-tasks lift, lower, push, pull, carry, turn and fold the first task was designed. It consisted out of 28 sub-tasks were every sub-task occured 4 times. During the design of the task became clear that an additional element had to be introduced: walking. This enables more variation in the task. For example, the task executer stands at the left side of the table and pushes the box away. Now the executor can walk to the left side and pull the box.

Lift and lower can be realised by lifting the box from the floor and lower the box to the floor. For push and pull, another artifact is necessary: a table makes the execution of push and pull easier than on the ground.

manual material handling [28], single: lift lower push pull carry hold, hold out because of confusion with speed mechanic, introduced carry because of variaation and flexibility in task. unit/combined mmh tasks classification. baua classification?

2.5 Related Work: Motor Learning in Virtual Reality

Training movements in Virtual Reality was investigated previously in several works. The preceeding seminar thesis (see chapter 3) provided an overview over 23 (compare table 2.3) of these works and evaluated six of them in detail: Tai Chi Trainer by Chua et al. [20], YouMove by Anderson et al. [1], VR Dance Trainer by Chan et al. [2], OneBody by Hoang et al. [19], LightGuide by Sodhi et al. [22] and Pyhsio@Home by Tang et al. [9]. Special attention was payed to the visual perspective, task, guidance visualisation and their independent and dependent variables they used in their investigations. Finnaly, the results were compared and the results of their works. An overview is depicted in table 2.2. This work is informed by these works in various aspects. Chua et al. used the ego & augmented exo-centric visual perspective, Hoang et al. and Sodhi et al. the ego-centric visual perspective. These visual perspectives prooved to be suited for the evaluation of motor learning in VR and is adopted for the proposed study design, compare section 2.3. Furthermore, Chan et al. and Chua et al. used high realisitc avatars as guidance visualisation, which are used in the proposed study design, compare seminar thesis chapter 3.3. Furthermore, recent research indicates, that high realism avatars outperforms abstract avatars [29, 30] All authors used a performance measure to evaluate the performend movements of the participants of their studies. Especially the distance based measures informed the measures used in the proposed study design, compare 2.2.1. The relatively new technology of Vive Trackers in combination with inverse Kinematics (see project report chapter 2.1 and 2.2) is not used by the above mentioned works. Sra et al. [31] used this technology in 2018 for their system Your Place and Mine to render human shaped avatars.
The results of related work yielded in no clear conclusion about the influence of the perspectives on motor learning. Chua et al. found no difference in the performance between the visual perspectives, Anderson et al. and Chan et al. found out that their exo-centric visual perspectives in Virtual Reality outperforms traditional video guidance. The works of Hoang et al. and Sodhi et al. conclude that the ego-centric perspective outperforms the exo-centric visual perspective. But an investigation of how the visual perspective influences motor learning was not investigated. Recently, in December 2020, Yu et al. [30] conducted three independent studies to close this gap. In the first study Yu et al. compared the ego-centric visual perspective and a 2D-mirror for single arm movements. In the second study they compared the ego-centric and exo-centric visual perspective for Yoga. In the third study they compared the ego-centric visual perspective with an 3D-mirror for arm movements. Yu et al. conclude their findings in a design guideline for systems training Motor Learning in Virtual Reality: use the ego-centric visual perspective if the type of motion allows, consider alternatives for other types of motions, ibidem. In all three studies the ego-centric visual perspective outperformed the other perspectives, if the movement was clearly visible from the ego-centric visual perspective. This work, in contrast, focus on full body movements that include the handling of physical load. Furthermore, this work provides a third visual perspective where the ego-centric and exo-centric visual perspective is combined.

	Tai Chi Trainer	YouMove	VR Dance Trainer	OneBody	LightGuide	Physio@Home
Perspective	Exo-centric, Ego & Augmented Exo-centric	Exo-centric	Exo-centric	Ego-centric, Exo-centric	Ego-centric, Exo-centric	Exo-centric
Task	Tai Chi	Dance (Ballet), abstract	Dance (HipHop)	Martial Arts	Abstract	Shoulder rehab
Guidance Visualisation	hr avatar, wireframe, mimic avatar	Stick figure, mimic avatar	hr figure, mimic avatar	Stick figure, mimic avatar	Indicators, follow/mimic	Indicators
Variables	Perspectives, performance measure	VR/Video, performance	Video/VR, performance	Training method, performance	Visualisations, Perspective, Performance	Visualisation, performance
Results	No difference in performance	VR better than video	VR better than video	Ego better than exo	Ego better than exo	Multi view better than single view

Table 2.2: Overview seminar evaluation

2.6 Research Contribution Statement

The conduction of the proposed study will produce data that serves as a reasonable basis for designers of VR Motor Learning systems. bekannte arbeiten und deren ergebnisse über motor learning in VR

auf basis dieses kapitels wird die studie geformt

Ego-centric	Exo-centric	Ego || Exo-centric
AR-Arm (Han et al. 2016)	MotionMA (Velloso et al. 2013)	OneBody (Hoang et al. 2016)
Just Follow Me (Yang & Kim 2002)	YouMove (Anderson et al. 2013)	LightGuide (Sodhi et al. 2012)
Gohstman (Chinthammit et al. 2014)	VR Dance Trainer (Jacky Chan et al. 2010)	MR Dance Trainer (Hachimura et al. 2004)
Stylo and Handifact (Katzakis et al. 2017)	Physio@Home (Tang et al. 2015)	Free Throw Simulator (Covaci et al. 2014)
GhostHands (Scavo et al. 2015)	OutSide me (Yan et al. 2015)	Training Physical Skill (Kojima et al. 2014)
	e-Learning Martial Arts (Komura et al. 2006)	SleeveAR (Sousa et al. 2016)
	My Tai-Chi Coaches (Han et al. 2017)	Tai Chi Trainer (Chua et al. 2006)
	Performance Training (Chan et al. 2007)	
	RT Gestrue Recognition (Portillo et al. 2008)	
	KinoHaptics (Rajanna et al. 2015)	
	TIKL (Lieberman & Breazeal 2007)	

Dance Sports Rehab Arts Abstract

Table 2.3: Overview Related Work divided by perspective and task

3 E(x|g)o- Design and Implementation

(15 pages)

3.1 E(x|g)o

Studysetup
frameworks
implementation
perspectives
mechanics
logging
limitations
iterative implementation
formative tests

3.2 Study

tasks
procedure
geplante evaluierung
limitations
bezug zwischen messungen und forschungsfragen
triangulation nutzen wo sinnvoll

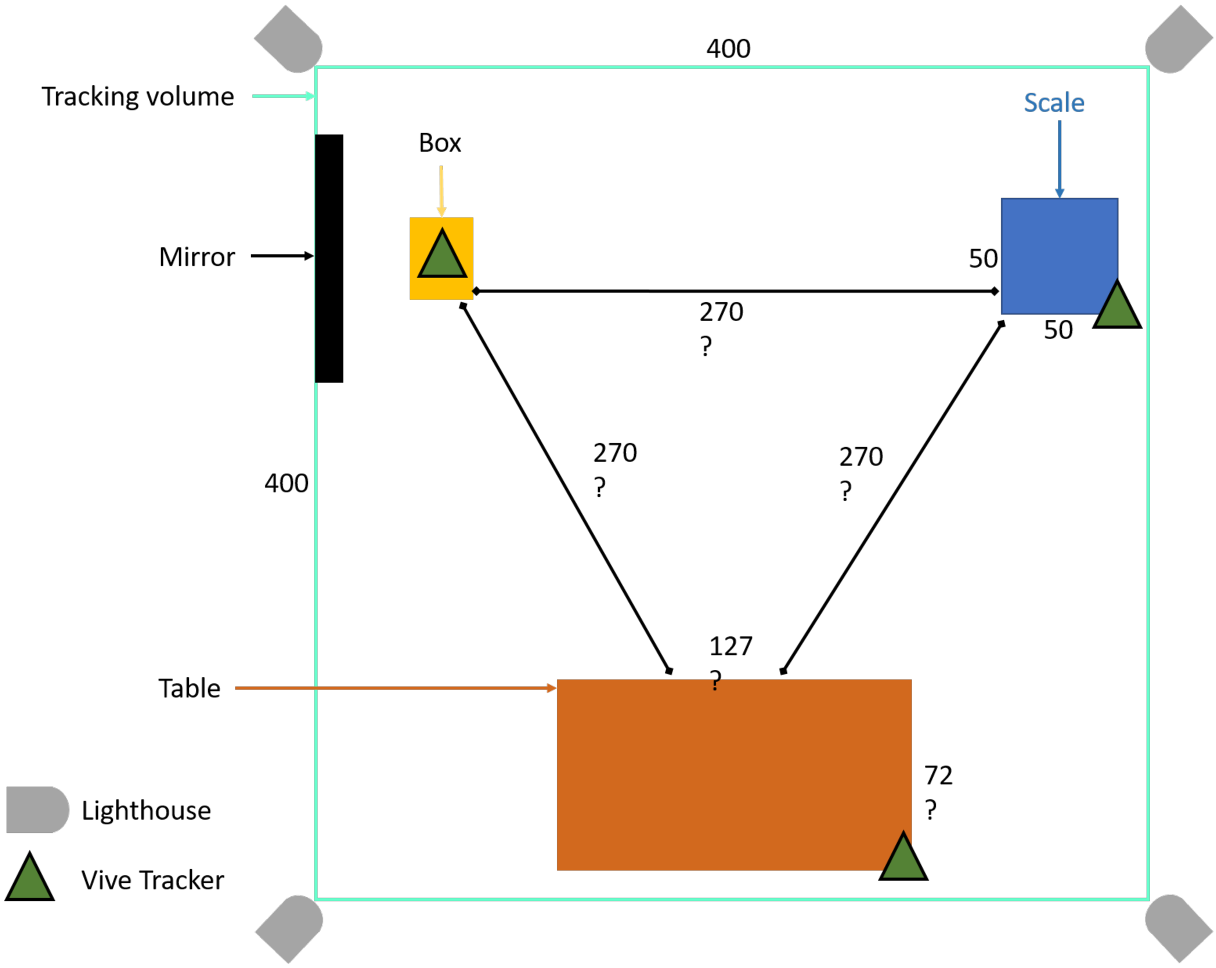

Figure 3.1: study setting

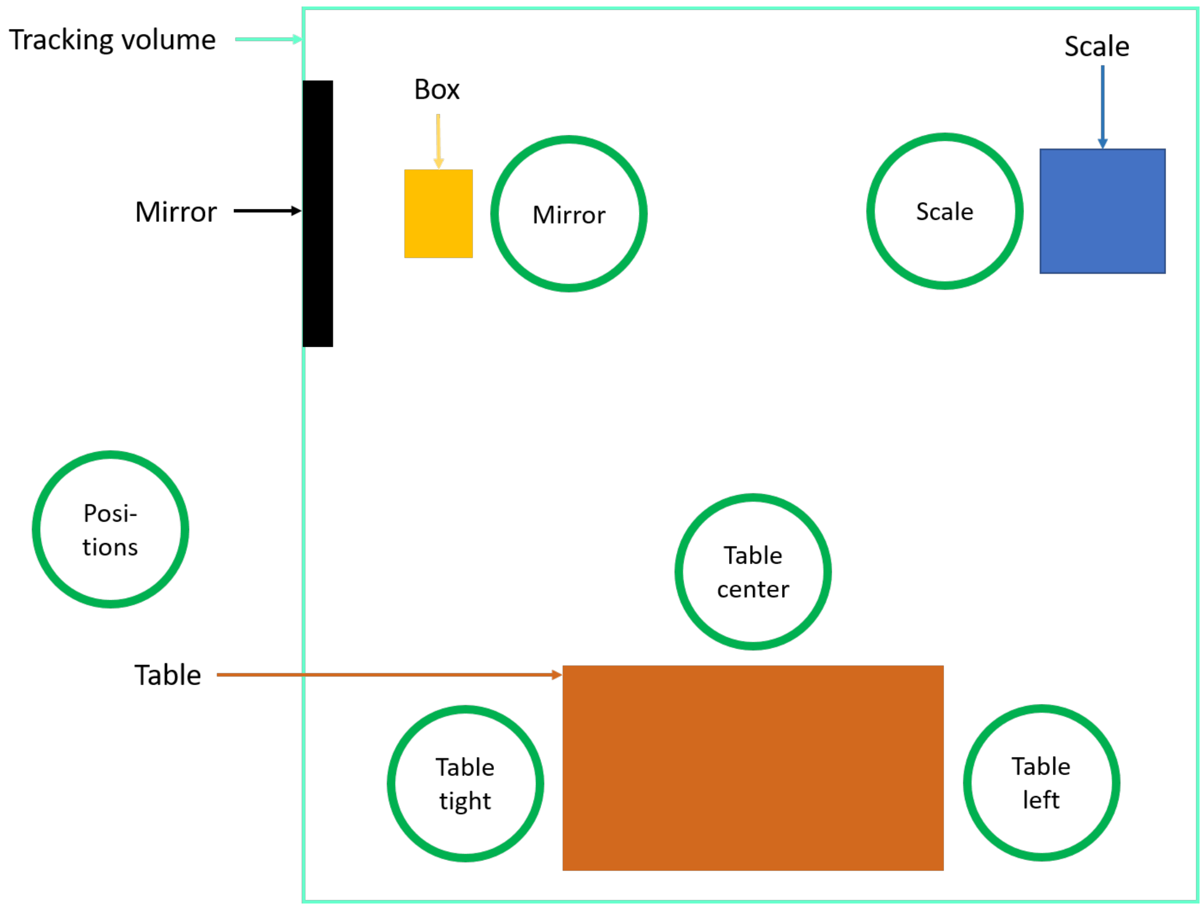

Figure 3.2: tasks

Logging ID	Description	Unit	Research question
Elapsed time	Time since the beginning of the task	Milliseconds	RQ1.1.1-3
Current animation Frame	Current frame of the GV animation	frames	RQ1.1.1-3
Subtask ID	The current sub task performed by L	STID	RQ1.1.3
Hip distance	ED between hip of the GV and the hip L	Meters	RQ1.1.1
Left hand distance	ED between left hand GV and left hand L	Meters	RQ1.1.1
Right hand distance	ED between right hand GV and right hand L	Meters	RQ1.1.1
Left foot distance	ED between left foot GV and left foot L	Meters	RQ1.1.1
Right foot distance	ED between right foot GV and right foot L	Meters	RQ1.1.1
Head distance	ED between head GV and head L	Meters	RQ1.1.1*
Box distance	ED between box GV and box L	Meters	RQ1.1.2
Hip angle	ED between hip of the GV and the hip L	Degrees	RQ1.1.1
Left hand angle	ED between left hand GV and left hand L	Degrees	RQ1.1.1
Right hand angle	ED between right hand GV and right hand L	Degrees	RQ1.1.1
Left foot angle	ED between left foot GV and left foot L	Degrees	RQ1.1.1
Right foot angle	ED between right foot GV and right foot L	Degrees	RQ1.1.1
Head angle	ED between head GV and head L	Degrees	RQ1.1.1*, RQ1.3
Box angle	ED between box GV and box L	Degrees	RQ1.1.2
L spine bend	RM spine bend of L	Degrees	RQ1.2
L foot distance	RM base of L	Meters	RQ1.2
L squat distance	RM squat distance of L	Meters	RQ1.2
L hip-box distance	RM elbows L	Meters	RQ1.2
GV spine bend	RM spine bend of GV	Degrees	RQ1.2
GV foot distance	RM base of GV	Meters	RQ1.2
GV squat distance	RM squat distance of GV	Meters	RQ1.2
GV hip-box distance	RM elbows GV	Meters	RQ1.2
L looking at	The object L is looking at	LAID	RQ1.3
Pos x	X position for all 12 trackers	Meters	**
Pos y	Y position for all 12 trackers	Meters	**
Pos z	Z position for all 12 trackers	Meters	**
Rot x	X rotation for all 12 trackers	Meters	**
Rot y	Y rotation for all 12 trackers	Meters	**
Rot z	Z rotation for all 12 trackers	Meters	**
Total 146 columns			

Figure 3.3: Detailed overview of logs produced by E(x|g)o per frame. L: learner, GV guidance visualistion, ED: euclidean distance. *head position and rotation is biased in exo-centric conditions because of multiple GV the L can focus on. **All trackers are logged for backup reasons: after the study is conducted a measurement can become interesting that was not of imporance before. With these values any measurement can be calculated post-study.

Task 1			Task 2			Task 3		
Sub-task#	Description	ST ID	Sub-task#	Description	ST ID	Sub-task#	Description	ST ID
	start in front of mirror, box on floor			start in front of mirror, box on floor			start in front of mirror, box on floor	
ST1	lift up box	lift	ST1	lift up box	lift	ST1	lift up box	lift
ST2	carry box to table	carry	ST2	carry box to scale	carry	ST2	carry box to table	carry
ST3	place box on table	place	ST3	lower box to scale	lower	ST3	place box on table	place
ST4	push box away	push	ST4	lift up box	lift	ST4	fold box away	fold
ST5	fold box away	fold	ST5	carry box to table	carry	ST5	walk to table center	walk
ST6	walk to left side of the table	walk	ST6	place box on table	place	ST6	turn box left	turn
ST7	fold box to bottom	fold	ST7	push box away	push	ST7	fold box to bottom	fold
ST8	pull box	pull	ST8	walk to right side of table	walk	ST8	push box away	push
ST9	pick up box	pick	ST9	pull box	pull	ST9	walk to right side of table	walk
ST10	carry box to scale	carry	ST10	push box away	push	ST10	pull box	pull
ST11	lower box to scale	lower	ST11	walk to table center	walk	ST11	fold box away	fold
ST12	lift up box from scale	lift	ST12	fold box left	fold	ST12	turn box right	turn
ST13	carry box to table	carry	ST13	turn box right	turn	ST13	push box away	push
ST14	place box on table	place	ST14	fold box to bottom	fold	ST14	walk to table center	walk
ST15	turn box left	turn	ST15	turn box left	turn	ST15	fold box to bottom	fold
ST16	push box away	push	ST16	push box away	push	ST16	turn box left	turn
ST17	pull box	pull	ST17	turn box left	turn	ST17	pick up box	pick
ST18	turn box right	turn	ST18	pull box	pull	ST18	carry box to scale	carry
ST19	fold box away	fold	ST19	fold box away	fold	ST19	lower box to scale	lower
ST20	pull box	pull	ST20	turn box right	turn	ST20	lift up box from scale	lift
ST21	walk to left side of table	walk	ST21	walk left side	walk	ST21	lower box to scale	lower
ST22	pull box	pull	ST22	pull box	pull	ST22	lift up box from scale	lift
ST23	turn box right	turn	ST23	fold box to bottom	fold	ST23	carry box to table	carry
ST24	push box away	push	ST24	push box away	push	ST24	place box on table	place
ST25	fold box to buttom	fold	ST25	walk to table center	walk	ST25	push box away	push
ST26	push box away	push	ST26	pull box	pull	ST26	pull box	pull
ST27	walk to scale	walk	ST27	pick up box	pick	ST27	turn box right	turn
ST28	walk to box on table	walk	ST28	place box on table	place	ST28	walk to right side of table	walk
ST29	turn box left	turn	ST29	pick up box	pick	ST29	pull box	pull
ST30	pick up box	pick	ST30	carry box to scale	carry	ST30	push box away	push
ST31	carry box to (invisible) mirror	carry	ST31	lower box to scale	lower	ST31	pull box	pull
ST32	put box on floor	lower	ST32	lift up box	lift	ST32	pick up box	pick
ST33	lift box up	lift	ST33	carry box to (invisible) mirror	carry	ST33	carry box to (invisible) mirror	carry
ST34	put box to ground	lower	ST34	lower box to ground	lower	ST34	lower box to ground	lower

Table 3.1: tasks

Sub-task ID	Sub-task description	Professional‘s description	#of sub-tasks/Task
push	Push box on table	Lunge, feet hip wide, chest out, shoulders back, straight back, lean forward, bend front knee, extend your arms, pressure on front leg, push box by activating back muscles	4
pull	Pull box on table	Lunge, feet hip wide, chest out, shoulders back, straight back, lean forward, bend front knee, extend your arms, pressure on front leg, pull box by activating back muscles	4
turn	Turn box by 90° on table	Feet hip wide, lean slightly forward with straight back, turn box with arm muscles, weight of the box remains on the table	4
fold	Put the box from one side to another on the table	Feet hip wide, straight back, slightly bended arms, depending on the distance to the box: lean over table, no bent knees, weight of the box remains on the table	4
carry	Translation in space with the box in hand	Chest out, straight back, bend elbows to 90°, box near to body, shoulder in neural-zero	4
walk	Translation in space without the box	“normal walking on their own judgment“, straight back	4
lift	Lift up the box from the floor	Approach box as near as possible, weight shifted slightly to the front, bend knees, open legs while going down, stop at the raised heels, lean forward with straight back, lift box with quadtriceps (tights), chest out, ellbows aim at ca. 90°	3
lower	Lower box to floor	Head above pelvis, bend knees and open legs, chest out, straight back and head, extend arms	3
place	Put box on table	Paralell hip wide feet, bend knees slightly, lean forward with straight back, lower arms	2
pick	Pick up box from table	Paralell hip wide feet, bend knees slightly, lean forward with straight back, lift with arms, abdominal and back muscles	2
			Total: 34 sub-tasks per task

Table 3.2: subtasks

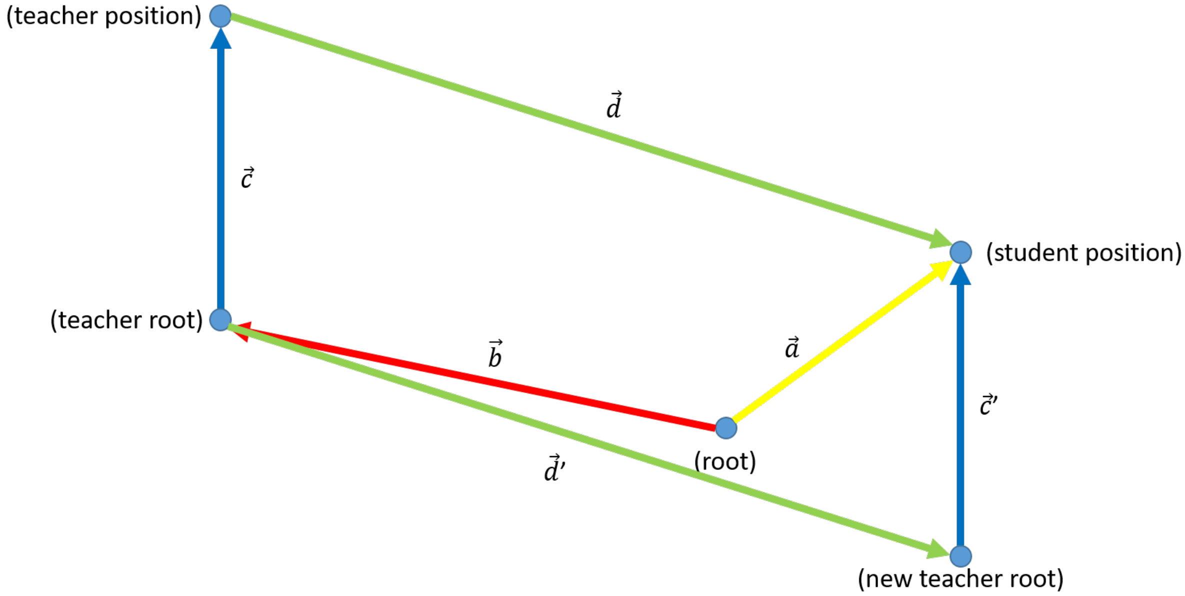

Figure 3.4: shift calc

	Session 1		Session 2		Session 3	
PT	Perspective	Task	Perspective	Task	Perspective	Task
PT1	Ego	T1	Exo	T2	Ego-Exo	T3
PT2	Ego	T3	Exo	T1	Ego-Exo	T2
PT3	Ego	T2	Exo	T3	Ego-Exo	T1
PT4	Ego & Exo	T3	Ego	T1	Exo	T2
PT5	Ego & Exo	T2	Ego	T3	Exo	T1
PT6	Ego & Exo	T1	Ego	T2	Exo	T3
PT7	Exo	T2	Ego-Exo	T3	Ego	T1
PT8	Exo	T1	Ego-Exo	T2	Ego	T3
PT9	Exo	T3	Ego-Exo	T1	Ego	T2

Figure 3.5: session plan

4 Study Evaluation

(5 pages)

4.1 Study Evaluation

aufgrund der Pilotstudie beschreiben, welche elemente gut bzw schlecht sind.
Wird gemessen was gemessen werden soll
sind die positionen der lehrer ok
sind tisch und box geeignet
gibt es schwierigkeiten etwas zu verstehen
ist die aklimatisierungsmethode angebracht
wie ist die dauer der durchführung einer session
sind die gestellten fragen am ende zielführend
pausen zwischen den sessions
sind die anweisungen die gegeben wurden zu viel/zu wenig
...
refinements

5 Conclusion

(3 pages)

5.1 System and Study

Zusammenfassung der Evaluation des Systems über die eignung zur durchführung einer Studie die daten generiert um die Forschungsfrage zu beantworten.
Zusammenfassung was gut und schlecht ist bei der Studienausführung.
reflexion und contribution, inkl. zu erwartende empirische contribution

5.2 Outlook

Was kann noch evaluiert werden mit diesem system?
anderer task ohne physical load, sitzend zur bedienung von maschinen ,realismusgrad der avatare, anzahl avatare, position von avataren, geschwindigkeit der anleitungsanimation...
wer hat welchen nutzen von der beantwortung der forschungsfrage: designer von motorlearning vr systemen.
bezug zu erweiterungen der implementierung
possible improvement: DTW https://towardsdatascience.com/dynamic-time-warping-3933f25fcdd

6 Attachments

6.1 Task description

6.2 Study Documents

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