

# Investigating the influence of avatar positioning on motor learning in MR

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July 18, 2019



# **Abstract**

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- Overall aim of the Seminar thesis: how to investigate the influence of perspectives on virtual avatars in MR for motor learning
- therefore analysis of motor learning, related work, research questions
- propose study setting

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# 1 Introduction

## 1.1 Motivation

In recent years, MR devices became more affordable <sup>1</sup>, portable <sup>2</sup> and usable in many conditions. Not only academic researchers are interested in this technology, commercial companies also found this technology helpful to explore new possibilities to use it profitable. EON <sup>3</sup> for example calls themself "the world leader in Virtual Reality based knowledge transfer for industry, education, and edutainment". They develop MR programs for several platforms, eg. with the aim to guide workers, reducing mistakes and thus reducing costs.

Since MR learning or guiding programs reached the commercial market, many applications will be created. It is important to build these applications on well founded research.

Developing a system for MR learning can be complex and mistakes can be made. Providing a developer with guidelines to design such a program could help decreasing design faults. But before guidelines can be created, groundwork has to be done and be investigated with sophisticated research methods. This seminar thesis will take a look in the background of motor learning and perspectives to later conduct this groundwork that can be used for guidelines for designing a MR motor learning system.

## 1.2 Problem definition and RQ

Various research show that motor learning can be supported by MR systems **TODO**. xyz, showed yxc... But very less take the perspective into account. In the real world the perspective on a teacher is always the egocentric perspective. To close this gap, gound work on how

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<sup>1</sup>**TODO**

<sup>2</sup>**TODO**

<sup>3</sup><https://www.eonreality.com/> accessed: 14.12.2018

- Motor learning tasks can be learn in MR (quellen)
- investigations in xyz but not in terms of perspective
- influence of perspective could lead to insights/ recommendations for learning in MR

Overall rq

- How does perspectives on virtual avatars influence motor learning?

### **1.3 Approach**

- Design a Study, participants to perform movements
- two groups, ego/exo perspective, 2 movement types
- investigate the performance of the groups

### **1.4 outline**

After this introduction, the scope of this thesis is given, where it is explained to what extend motor learning, MR, perspectives and other factors are considered. The following related work part will give an overview about other MR learning systems and also work about perspectives on avatars. From this work the measures, dependent and independent variables and tasks are derived. Taking the related work into consideration a study design is proposed in outlook section.

# 2 Theoretical Background

## 2.1 Movements

### How do we learn movements

We learn MR by mimicking others, follow textual descriptions, videos etc. **TODO**

### Movement classification

For a simplified discussion a classification of movements is provided in the following. There are two important classification schemes. The first one is based on the particular movements performed and are divided into *discrete*, *continuous* and *serial movements*. The second one is based on perceptual attributes of the task and are divided into *open* and *closed skills*. Both classification representing a continuum.

#### Discrete, Continuous and Serial Movements

**Discrete movements** are located on the one end of the continuum. These are movements with a recognisable beginning and end. The end of a discrete movement is defined by the task itself and can be very rapid like blinking or longer like making the signing. Examples are kicking a ball, shifting gears in a car or striking a match

**Continuous movements** are located on the other end of the continuum. These movements don't have a recognisable start and end, with behaviour continuing till the movement arbitrarily stopped. Continuous tasks tend to be longer than discrete tasks. Examples are swimming, running or steering a car.

**Serial movements** are located in the middle part of the continuum. Following the nature of a continuum these movements are neither discrete nor continuous. They can consist of smaller movements tied together. Furthermore, discrete movements can be rather long but are not stopped arbitrarily.

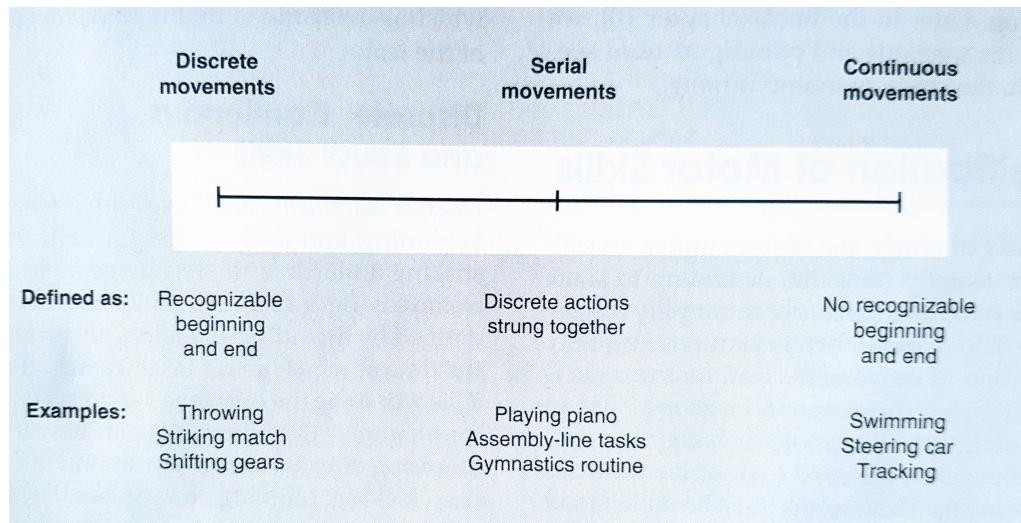


Figure 2.1: Continuum of movements buch [6]

Serial tasks can be seen as many discrete tasks strung together and the order (and sometimes timing) is important. Examples are starting a car or preparing and lighting a wood fireplace.

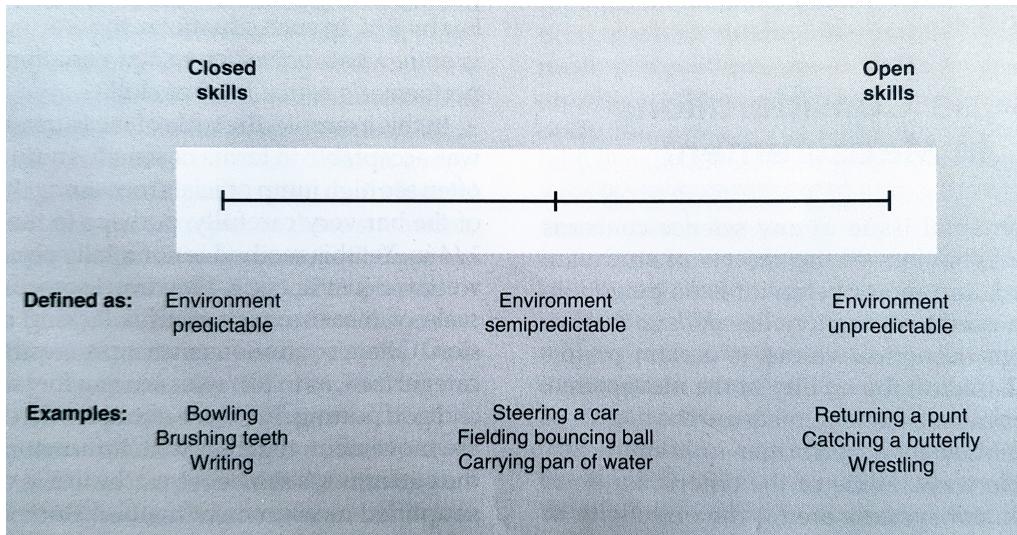
### Open and Closed Skills

**Open skills:** The environment is constantly, unpredictably changing, so the performer cannot plan his activity effectively in advance. Own movements depend on the environment. For example, if a ice hockey player shoots a shot in ice hockey, his own movement is dependent on the movement of the keeper. Another example is driving on a free way. The driver needs to adjust his own driving dependent on the behaviour of the other cars. Success in open skills is largely determined by the extend to which a individual can adapt the planned motor behaviour to the changing environment.

**Closed skills:** The environment is predictable, mainly because it is stable. This means that the performer can plan his activity in advance. Examples are bowling, archery or singing. **TODO+** citations

### How to quantify movements

Judging motions and matching them to a given motion is not a trivial task. One approach follows Rudolph von Laban - a professional dancer. Von Laban developed a broadly used dance notation. His work lead to the *Laban*

Figure 2.2: Continuum of skills [6] **TODO**seite

*Movement Analysis* with which human movements could be quantized.<sup>1</sup> There are four main components to systematically describe movements in the *Laban Movement Analysis*: body, effort, shape and space. Each component can describe movements independently or combined. Hachimura et al. [2] used the methodology of *Laban Movement Analysis* and adopted it to for digital movements.

Yoshimura et al. [8] followed a similar approach from another dance movement description theory called *furi*. *Furi* is also described by four so called *indices*: *kamae*, *jyu-shin*, *koshi*, *uchiwa*. Yoshimura at all could map these indices to concrete markers on the body of a performer. Qian et al. [1] developed a gesture recognition system for performing arts. To match the motions ten body parts were defined: head, torso, upper arms, forearms, upper legs and lower legs. For each body part the Mahalanobis distance is calculated to an ideal point. The Mahalonobis distance describes the distance between point  $p$  and distribution  $D$ . Kwon et al. [3] **TODO**

- K. Hachimura, K. Takashina, and M. Yoshimura, “Analysis and Evaluation of Dancing Movement Based on LMA,” Proc. IEEE Int’l Workshop Robots and Human Interactive Comm., pp. 294-299, 2005.
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<sup>1</sup>Brockhaus, Rudolf Laban. <http://www.brockhaus.de/ecs/enzy/article/laban-rudolf> (accessed 2018-10-25)

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- D.Y. Kwon and M. Cross, “Combining Body Sensors and Visual Sensors for Motion Training,” Proc. ACM SIGCHI, pp. 94-101, 2005.
- vr dance trainer

## How to measure movements

In order to judge if a movement is performed correctly methods need to be applied to measure the error of a performed action. In literature, three main categories are listed: error of a single subject, measures of time and speed and measures of movement magnitude.

### Measures of Error for a Single Subject

Measures of error for a single subject represent the degree to which the target was not achieved. A target can be to perform an act at a particular time (time stamp), move with a certain force (amount of force) or hit a spatial target (a point in spatial volume). The attribute of the target serves as the variable in question, see braces behind the examples. The error itself describes the distance - in regard to the dimension - from the target. The following list gives an insight to the most important error measures.

- **Constant Error** describes the average error between the actual accuracy and the target. Means, in average the performer missed the target by CE.

$$CE = \frac{\sum(x_i - T)}{n} \quad (2.1)$$

with  $x_i$ : score,  $n$ : number of values,  $T$ : target value.

- **Variable Error** measures the inconsistency in movements. The more consistent the movements, the smaller  $VE$ .  $VE$  does not depend on whether or not the subject was close to the target.

$$VE = \sqrt{\frac{\sum(x_i - M)^2}{n}} \quad (2.2)$$

- **Total Variability** describes the total variability around a target. The combination of VE and CE represents the total amount of spread about the target. It is an overall measure how successful was the subject in achieving the target.

$$E = VE^2 + CE^2 = \sqrt{\frac{\sum(x_i - T)^2}{n}} \quad (2.3)$$

with  $x_i$ : score,  $n$ : number of values,  $T$ : target value.

- **absolute error** is a measure of the overall accuracy in performance.

$$AE = \frac{\sum |x_i - T|}{n} \quad (2.4)$$

with  $x_i$ : score,  $n$ : number of values,  $T$ : target value.

- **Absolute Constant Error** is the absolute value of  $CE$ . Because of negative and positive values can cancel each other out

$$ACE = |CE| \quad (2.5)$$

these measures can be applied to other movements. like pursuit motor: TOT, Mashburn task, stabilometer, two hand coordination task.

### Measures of Time and Speed

measures of time and speed: basic to this idea: performer who can accomplish more in a given amount of time or who can accomplish a given amount of behavior is more skillfull. time measure:  $c \frac{time}{unit}$ . speed:  $\frac{units}{time}$ .

reaction time (RT): can also be a performance measure. a measure of time from the arrival of a sudden and unanticipated signal to the beginning of the response.

### Measures of Movement Magnitude

movement time (MT): how long does the movement last. sometimes combined with RT: response time=  $RT + MT$

### Movement Classification

eg. Postural, Transport, Manipulation. p4 in motor learning, principles and practices **TODO** after analysis



Figure 2.3: Mixed reality continuum by Milgram et al. [4]

## 2.2 Mixed Reality

Mixed reality continuum [4]

## 2.3 Perspectives

Wang and Milgram [7] describe the perspectives on the centricity continuum see figure 2.4. On the most left hand side of the continuum the egocentric perspective is located. Egocentric means that the anchor of the viewport camera is located inside the object to control - for simplicity, this object in question is referred as avatar. On the left hand side the exocentric perspective is located. This viewport camera is a fixed camera in the scene not to be controllable. The exocentric perspective gives the user the possibility to examine the scene from a bird's-eye view. The movement or angle of the avatar has no influence on the cameras position or angle. So the main difference is the so called tether distance and the degree of freedom of the camera. Milgarm and Wang investigated on tethered cameras and define it as the distance between the avatar and the camera which is following the avatar. This describes the middle part of the continuum. Zero-distance camera describes the egocentric perspective. The longer the tether distance the more the perspective is located on the right of the scale to the exocentric perspective. They also distinguish between dynamic and rigid tethering relationships. A dynamic tethered camera is controlled by the user in all six dofs (**TODO**) while a rigid stands like a pole and can only be controlled in 3 dofs. Rigid tethered cameras are common in modern 3rd person computer games.

## 2.4 VR Technologies

HMD, 3D screens, tablets

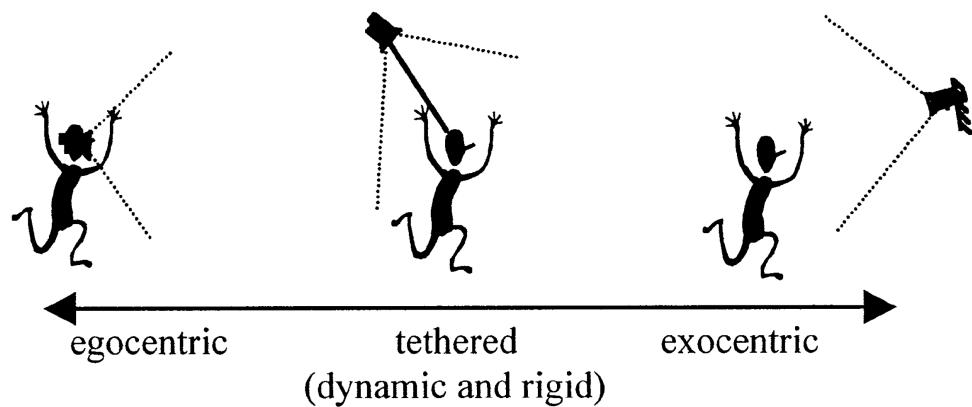


Figure 2.4: Centrality continuum by Wang and Milgram 2001 [7]

## 2.5 Motion Tracking Technologies

External vs. internal tracking. Drift problem, accuracy



# **3 Scope**

## **3.1 Motor Learning**

- discrete movements
- closed skills
- at least 2 different movement categories
- how to measure movements
- posture vs movement

## **3.2 Mixed Reality**

- Milgram
- AR or VR

## **3.3 Perspective**

## **3.4 Misc**

- synchron asynchron
- colocated/remote
- perspective
- hardware?
- feedback!
- real world, not abstract avatars

- only visuals - no audio or textual explanation

# 4 Related Work

## 4.1 Aggregated overview about paper describing MR learning systems

nur gedankenst tze: "In order to create a study design to evaluate the perspective and learning we here take a look on how other researchers conducted their studies"

### Method

Jacky Chan et al. **TODO**created a VR dance training system using an optical motion capturing system to compare the movements performed by the student with movements from the avatar. These movements are presented to the student as a 3D rendering on large screen. The movements of the students are visualised on the same screen as a coloured stick figure. The student mimics these movements and gets instant feedback as well as a feedback as a summary.

In contrast, Onebody by Hoang et al. **TODO**use a VR headset for a first person remote posture guidance system.

### Tasks

In Chan et al. **TODO**the dance student is presented a virtual avatar performing dance moves of A-go-go or Hip-Hop style. The avatars movement is based on the motion capturing data of a professional dancer. Onebody **TODO**is not only restricted to dance moves but also include other posture based sports or physical activities like Yoga or Mixed Martial Arts.

Onebody **TODO**uses a number of martial arts postures or stances.

## Measures and variables

Jacky Chan et al. **TODO**defined 19 body parts that are considered in the measure of the performance of the dancing student. They name three features to compare the difference between two motions common: joint position, joint velocity and joint angle. Chan investigated which of these features suits most to judge the two dancing motions. The outcome of this investigation names the joint position to have the highest discriminative power. Hence, the joint position suits them best for their evaluation, Chan et al. calculate a score of the position error for each of the defined body parts, as well as an overall score.

Onebody **TODO**uses skeletal of the instructor and the student "Posture accuracy is determined by the extend to which the student can replicate the final posture as instructed and demonstrated as by the instructor." Independent variable: mothods for posture training. dependent variables: performance factors of posture accuracy, completion time, subjective instructor rating, users preference.

## 4.2 Detailed description of 6-10 papers incl. Table

### Onebody: Remote Posture Guidance System using First Person View in Virtual Environment

Hardware: Kinect, Oculus Rift

Task: sports, dance, martial arts, yoga

Perspectives: First Person of the teacher

Measures: Position, completion time, subjective score

investigation: comparing different remote guidance systems: onebody, pre recorded video, video conference, VR third person

variables: Independent: training method, dependent: performance

Onebody by Hoang et al. [5] is a VR system for remote posture guidance. Onebody is designed for sports or physical activity training like yoga, dance or martial arts. The student and the teacher are both tracked by skeletal tracking. The visualisation of this tracking are shown via a VR headset, allowing the student to follow the instruction of the teacher in first person

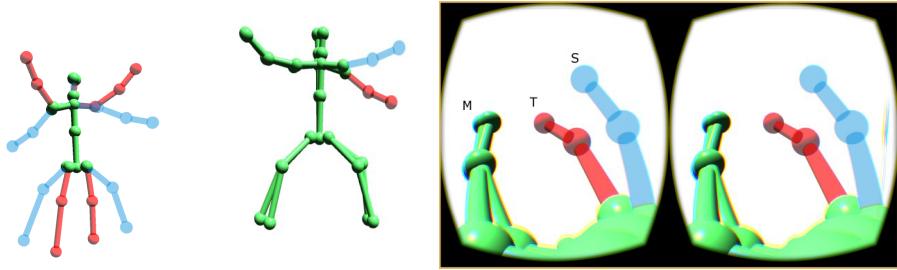


Figure 4.1: Left: student avatar (blue) and teacher avatar (red). Green limbs are matching limbs. Right: students view on the scene. [5]

view of the teacher - which means the student "stands inside the body of the teacher". Both, the student and the teacher are visualised by stick figures. The teachers avatar is red, the students blue and matching joints are green like shown in figure 4.1 left. Figure 4.1 right shows the scene from the first person perspective. When the teacher moves his limbs, the student can see the movement emerging from himself. Now the student can move his own limbs to mimic the movement till the teachers posture is matched. The teacher sees the students limbs likewise allowing him to give instant feedback to the student. Thus, "Onebody provides a medium to deliver body movement instructions for non-collocated instructor and learner." **TODO**. The visualisations are attached to the hip but keeps the mapping between the user and corresponding avatar. To overcome different body sizes, the avatars are normalised and scaled to the size of the person seeing the avatars.

For transferring data, both the teacher and the student are clients in a server-client system. The clients are sending their tracking data to the server which is broadcasting it to the clients. The comparison of the limbs for colour coding is performed on the client side. The matching of the limbs is calculated by the position of the single limbs (see equation (2.1)) with a threshold of 5cm to reduce jitter and tracking errors. Limbs in question are wrist, elbow, shoulder, hip, knee and ankle. The feedback with colour codes is provided in realtime.

With this system hoang et al. designed a user study to evaluate the performance of posture accuracy and user's preference. Their main hypotheses is "*Onebody delivers better posture accuracy than existing remote movement instruction methods*". "Posture accuracy is determined by the extend to which the student can replicate the final posture as instructed and demonstrated by the instructor." In addition, completion time and a subjective score of the instructor are considered. To test the hypothesis, Onebody

	<i>Video</i>	<i>Skype</i>	<i>VR-3PP</i>	<i>Onebody</i>
<i>Synchronous Interaction</i>	No	Yes	Yes	Yes
<i>VR Medium</i>	No	No	Yes	Yes
<i>1<sup>st</sup> Person View</i>	No	No	No	Yes

Figure 4.2: Training methods and their differences used in the study to evaluate Onebody [5]

was compared with three other remote posture training methods (independent variables): pre recorded video, video conference (Skype), VR 3rd person perspective. Each of the systems differs to Onebody in terms of synchronous interaction, VR medium and perspective see figure 4.2. The study was a 4x4 within subject. Each participant stated with a training session in which the not collocated instructor teach a posture physically and verbally. Verbal feedback was given the training repeated until the student was confident. After that the final posture was recorded. A set of four of postures with every system were performed with different complexities. The results show a significant difference in accuracy. Onebody performed significantly better in over video conference, 3rd person VR and pre recorded video. Furthermore, the completion time was significantly higher with Onebody as in the other three systems. The subjective score of the instructor showed no significant differences. A post questionnaire indicated that Onebody is harder to understand and use than the other systems, but at the same time it also indicated that Onebody was perceived to be more exact. Participants rated video conference as their most preferred system over Onebody and 3rd person VR.

## A VR Dance Training System Using Motion Capture Technology

Hardware:

Task:

Perspectives:

Measures:

investigation:

variables:

Name	Hardware	Perspectives	Task	Measures	Variables
Onebody					
VR dance trainer					

### 4.3 Research Gap

### 4.4 Conclusion (and research questions/hypotheses?)

hier wird zusammengefasst was ich abgeleitet habe und direkt in das studien design einfließt. danach folgen die genauen RQ und hypotheses.

#### Conclusion of VR motor learning systems



# 5 Outlook

## 5.1 Preliminary Study design

### Aim of the Study

The aim of the study is to investigate the influence of egocentric and exocentric perspectives on a virtual avatar during motor learning tasks.

### process

There are two groups: one learn only with the egocentric perspective, the other one with the exocentric perspective on the virtual avatar.

To derive conclusions on body regions, every participant learns movements for three different body parts. The body parts are:

- *upper body*(UB)
- *lower body*(LB)
- *full body*(FB)

To derive conclusion on movement types, two different movements per body part is learned. The two movement types are:

- mirrored movements
- independent movements

	UB	LB	FB
Ego	1 mirrored and 1 asynchronous movement	1 mirrored and 1 independent movement	1 mirrored and 1 independent movement
Exo	1 mirrored and 1 independent movement	1 mirrored and 1 independent movement	1 mirrored and 1 independent movement
Ego/Exo	1 mirrored and 1 independent movement	1 mirrored and 1 independent movement	1 mirrored and 1 independent movement

## Independent variables

- perspective on the avatar (Ego/Exo centric)
- body parts (*upper body, lower body, full body*)
- movement types (mirrored/independent movements)

## measures

TBA

## 5.2 Timetable

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