FollowMe: Supporting Independent Self-Directed Learning of Kinaesthetics-based Patient Transfer Movements in Mixed Reality by providing essential Feedback

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by
Tanveer Singh Mahendra
(01/867038)

at the

Universität Konstanz

Human Computer Interaction
Computer and Information Science

Evaluated by
Prof. Dr. Harald Reiterer

Abstract

In today's hyper-aged society, providing mobility care to elderly people has become an important challenge for geriatric nurses. One substantial part of mobility care is patient transfer. Nurses who care about these patient transfers, desire for better practical training and knowledge transfer during their course of study, and real-world practice. Such requirements can be benefitted by recent technological advancements in mixed reality technologies. When it comes to learning these patient transfer movements, there are some previous works that have explored domains with a single entity in the picture. However, we have quite less information about virtual movement learning systems that support a second actor. This paper investigates how humans learn movements in stages and explore the effectiveness of various feedback modalities across these stages. Additionally, it discusses specific aspects from the domain of mobility care and kinaesthetics to get a glimpse of what specifically needs to be addressed in terms of movement training. From existing research in the domain of kinaesthetics and movement learning, we define some requirements which are needed to be addressed by our system. Later we take a look at relevant existing systems that support training movements and assess them on the basis of the requirements that we have gathered. Furthermore, the paper explores the potential of applying this information to visualise an optimal virtual training system with two actors in a scenario consisting of patient transfer. This virtual system focuses on provisioning essential feedback to the learners during various stages of their learning process.

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1. Introduction

To start with, this particular chapter covers the motivation behind our literature research related to developing a digital training system for patient transfers. The motivation is strengthened by realising the limitations in the current training system. In the later part, the chapter defines our goal by giving an overview of what our envisioned system would achieve and how it will be extending certain works already produced in the same direction as ours.

1.1 Motivation

Demographics data of the elderly population (people aged > 65 years) shows that there has been a consistent growth in the elderly population of all the countries. According to the Organisation for Economic Co-operation and Development (OECD), Germany is among the top three countries with the highest elderly population percentage (21.45%) (Figure 1). In light of the aforementioned demographic change, it is expected that by 2050, more than

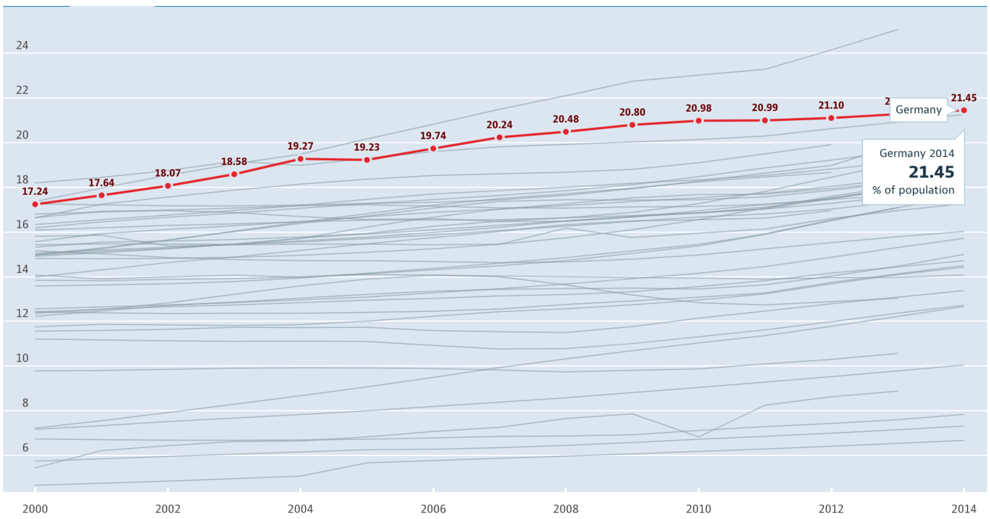

Figure 1: OECD elderly population survey graph.

twice as many people will be in need of care. Due to the foregoing reason, Germany has to face certain economic as well as social challenges. One of the social challenge beings, increasing the number of nursing-care professionals. According to the Skills Gap Analysis published by the Federal Employment Agency (Bundesamt für Arbeit), there are only 19 candidates for every 100 geriatric nurse vacancies. One of the many responsibilities of these nursing care staff is to help the patients with their mobility which includes transferring them - from sitting on the bed to the wheelchair or from a supine position to higher up in bed. As we got to know that one substantial part of mobility care is patient transfer - is also a major cause of risk in nurses. These physical risks include detrimental effects like injuries and musculoskeletal strain leading to back pain[42]. Musculoskeletal Disorders or MSDs are injuries and disorders that affect the human body's movement or musculoskeletal system (i.e. muscles, tendons, ligaments, nerves, discs, blood vessels, etc.). Other common names for MSDs are "repetitive motion injury", "repetitive stress injury". And it has been found that nursing facilities are among the high-risk sectors for musculoskeletal disorders (MSDs) [9]. This means there is a need to properly train more nurses in an effective manner to assist the elderly population in the near future. This has risen an issue regarding the health of current nurses. It has been shown that especially hospital nurses and nursing aides are at higher risk to suffer from work-related musculoskeletal disorders (WRMDs) [11]. One major risk factor being the transfer of patients [12, 13]. Since the work involves handling the transfer of patients, there are certain measures into a place covered by Kinaesthetic training to promote the overall physical well-being of the nurses as well. Recent developments have shown that the nurses are suffering from physical issues like lower-back pain due to improper postures during the transfer of the patients [14]. Also on the patient's side, there are some critical issues, for example, they should not be handled from body-joints. These improper practices need to be addressed with adequate training and guiding methods. In order to reduce the occurrence of MSDs, medical schools in Germany teach their students to handle and transfer patients based on the kinaesthetics care conception. We hereafter refer to these patient-handling and patient-transfer movements as *kinaesthetics movements.*

1.2 Current limitations

In the existing curriculum, nursing-care students mostly only take part in one basic kinaesthetics practical training course over three nonconsecutive

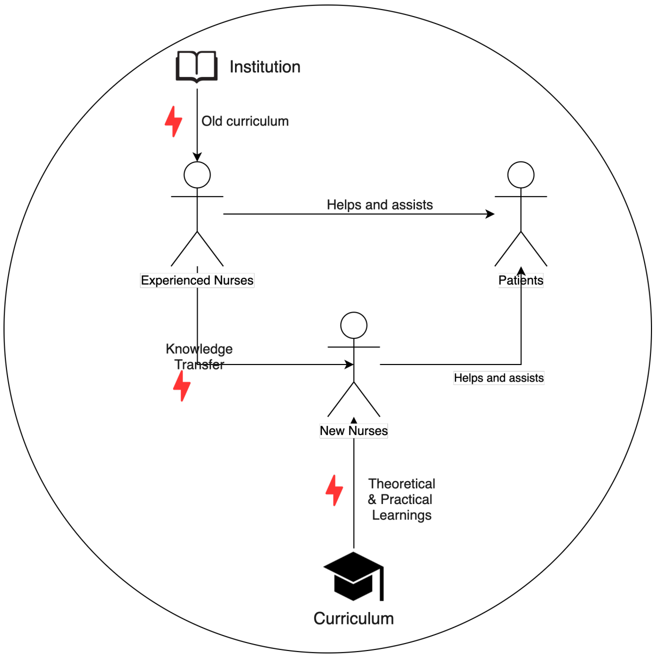

Figure 2: Current system and its limitations

days in a formation of three years. Apart from this course, typically no further support for learning kinaesthetics transfers is provided by educational institutions [10]. But, after the nursing-care students are deployed in a real-world setting, there is no significant knowledge transfer from the experienced nurses to the newly joined inexperienced ones [10]. For many years, professionals in the domain of healthcare and welfare are trained with different Kinaesthetics programs to learn new movement patterns and therefore reduce work-related musculoskeletal pain. After the basic Kinaesthetics training during the curriculum nurses still reported “a further need for practical and theoretical support". We further discuss how these practical training concerns can potentially be addressed with the help of technology. The overall limitations of the current system are highlighted in Figure 2.

1.3 Goal - A solution concept

Current virtual learning approaches to support movement training for a single individual [1]. Those are not necessarily effective in a scenario where two actors are involved and act as variables for learning. Therefore, there is a required need for such an independent self-training system in the field of medical training, especially for kinaesthetics movements learners. Such a system would facilitate practicing kinaesthetics movements from a performer's view so as to learn and improve effectively. The aim here is to study various aspects of motor learning with respect to the learning of patient transfer movements and to design a potential system to address the issues previously stated. The goal of the envisioned system here would not be to help a learner perform a 1:1 exact movement. But, the objective here is to help a beginner or intermediate kinaesthetic learner to gain an overall understanding and reflect on their training. This is to be done by delivering the learner with essential feedback with respect to their expertise. Narrowing on the feedback, the system would allow the learner to analyse their movement in real-time and also after they have been performed. This kind of mechanism would allow the learner to gain a better understanding of the dynamics of a movement with respect to certain thresholds. For example, how much they should bend their knees and lower back or how much should they twist themselves. To achieve this we would focus our implementation platform to be in a mixed-reality realm. This is because previous researches have shown promising applications of MR technologies into developing system for motor learning. However, these systems mostly focused only on upper-body [7][26], lacked involvement of second actor [1][2] or simply did not address complex motor tasks. We would address these shortcomings in our system by introducing a second actor in the scene where the learner can understand details related to complex kinaesthetics movements. These details being fed to the learner as a part of various feedback mechanism that we will discuss in detail in later chapters. Furthermore, we try to extend previous work by also providing feedbacks relevant to the learning stage the user is currently in.

1.4 Outline

The focus of this paper is to understand how humans learn movements and apply those principles to support virtual movement learning with an additional actor involved in the scene. We additionally discuss the context of Kinaesthetics in more detail and deduce the requirements based on the application context. The investigation extends into how a user's learning progress may be affected based on the adaption of feedback. Furthermore, we explore work related to mixed reality (MR) display technologies, why they are relevant to our context, and how they can be useful in achieving our goal for self-directed independent learning of movements.

2. Kinaesthetics & Motor Learning

Before we dive into the details of literature related to technicalities/implementation of our system, it is essential to lay a foundation of two fundamentals that are crucial for us. These two fundamentals influence what our system requires to support so as to effectively aid in the motor learning of kinaesthetics-based patient transfer movements. We first understand the pre-requisites of transferring a patient and how kinaesthetics training influences it. Then we understand the philosophy behind kinaesthetics and how it is to be realised. Furthermore, we look at the fundamentals of how humans learn movements irrespective of any subject matter. In the later part, these fundamentals help us to define the requirements that our system should cover so as to be effective in aiding the training of patient transfer movements.

2.1 Patient transfers as a part of mobility care

Mobility is an elementary human action that is required to achieve daily living activities by humans. It is also required to maintain biological functions for our bodies. The physical aging process affects mobility which leads to reduced muscle strength and function, joint stiffness, and reduced range of motion - to name a few [41]. Across all the settings - in-home, hospital care, and nursing home care - nurses take care of patients with mobility impairments [40]. This suggests that nursing staff are in a key position to provide mobility enhancing strategies while supporting care-dependent persons with their daily activities. One of the substantial parts of mobility training is transferring patients. Therefore, nursing staff should have the competence to improve, maintain, and support care-dependent persons' mobility while supporting them with their daily activities. Patient transfers include a range of interventions, e.g. supportive equipment and techniques to help patients transfer from one place to another, aimed at promoting mobility and movement [40]. In our research, we mainly try to focus on patient transfers. Competence in mobility care is also important since wrong or suboptimal work techniques could cause undesirable events for the care-dependent person and nurses themselves. An overlooked factor most of the time is the health of nurses assisting the patients during such care routines. Nursing staff's adverse events, when performing patient transfers include injuries and musculoskeletal strain leading to back pain [42]. This raises a concern to develop nursing staff competence were they are aware of correct practices required for their and patient's overall well-being.

In brief, nursing staff needs knowledge, skills, and appropriate attitude, e.g. person-centered care to enhance the care-dependent person's mobility and protect their own health. To achieve this desired goal, different training approaches are incorporated in the nursing curricula [43][44]. These approaches exist so as to develop the nursing staff's competence for patient transfers. The approach most often trained in European and especially in German-speaking countries (Germany, Austria, and Switzerland) is kinaesthetics[45].

2.2 Kinaesthetics and its training

Kinaesthetics is the study of movement and perception, which in turn originates from motion - it is the teaching of the sensation of movement [46]. It aims to develop the nursing staff's fundamental understanding of the interaction and human movement. The focus of kinaesthetics training lies in the movement support of a care-dependent person in daily activities. By raising awareness of one's own movement and the counterpart's movement, students learn to adapt the support in a health-promoting way. The support is also seen as a learning opportunity for the person in need of care [46]. A central element of kinaesthetics training is the kinaesthetics concept system, a teaching tool that is used to observe and describe human movement activities from different perspectives. It consists of six concepts (also known as dimensions): interaction, functional anatomy, human movement, human functions, effort, and environment (Table 1). Let's understand these so as to make an informed choice for deciding the requirements of our system later in this chapter.

Kinaesthetic awareness is related to the potential to move and the movement ability, to be able to feel your own limitations and possibilities ([52], [53], [47]). In nursing care, nurses and patients interact often through force and motion. As such, nurses' understanding of kinaesthetic interaction is very important for nursing care. Nursing students initially learn to understand each of these concepts with regard to their own bodies as well as in relation to a care situation. They learn and understand the relationship between the quality of their own movement and the participation of a care-dependent person in activities of daily living [46] [11]. In Germany, Austria, and Switzerland kinaesthetics training is integrated into vocational nursing education and is also offered as continuing education in different health care settings, e.g. hospital or home care.

Concept	Content
Interaction	The concept interaction addresses the following topics: senses (sense of sight, hearing, smell, taste and touch), movement element (time, effort and space) and forms of interaction (simultaneous-mutual, stepwise and unilateral interaction). The quality of interaction via personal contact and motion is central for the learning processes of the care-dependent person.
Functional anatomy	The human body consists of stable body parts (e.g. head, chest, pelvis) and space in between / joints (e.g. neck, waist, axilla) which have different functions and characteristics. Another aspect of this concept is orientation, meaning the ability to orient in the room and within one's own body. The interaction of these aspects allows to move the body with less effort and greatest possible control.
Human movement	The concept of human movement is not only concerned with movement from A to B, but also with posture and coordination necessary to organize the body's weight against gravity. One way to categorize human movement is to divide movement patterns into parallel (two-dimensional) and spiral (three-dimensional) movement.
Effort	A certain effort is needed to carry out movement. Two factors describing the characteristics of effort are pulling and pushing. When pulling, we use muscle strength to pull a part of the body to another part of the body. With pushing, we use muscle strength to push a part of the body to another part of the body. Extremities play an active role in pulling and pushing.
Human functions	Different functions of movement are classified into two categories: simple functions and complex functions. Simple functions are positions, e.g. lying, sitting. Complex functions are divided into movement without change of place (e.g. eating, elimination) and movement with change of place (e.g. walking, running). Simple functions are the foundation for complex functions.
Environment	Adjusting the physical environment by using the right equipment in the right place at the right time increases better interaction, facilitates locomotion and reduces physical strain.

Table 1: The six dimensions of every Kinaesthetic-based interaction by A. Fringer[11]

As mentioned in the introduction, there is a need for better training of nurses to facilitate correct methods so as to avoid detrimental effects like work-related musculoskeletal disorders (WRMDs) for example: lower back pain.

Kinaesthetics training and its application into a real-world setting have proven to be useful. Kinaesthetics expert reports and few case studies [49] [50] indicate a positive effect of kinaesthetics training on patients/clients and nursing staff. For nurses, the benefits of Kinaesthetics are better body awareness and a reduction in physical strain while moving and positioning patients. Thus, Kinaesthetics can have a preventive effect on developing musculoskeletal disorders [48]. We look further into the six dimensions of the kinaesthetics concept system so as to define a foundation of essential requirements required to be fulfilled by our supporting system.

Each of these dimensions is present in every interaction and can be used for a systematic analysis of human movement resources. Using these dimensions, Kinaesthetics concept mainly deals with the following contents ([49, 46, 47]):

1. The development of differentiated and conscious perception of one's own movement.
2. The development of one's own movement competences, that is, healthy and flexible use of their own movement in personal and professional activities.
3. The differentiated analysis of human activities through the experiential perspective of Kinaesthetics.
4. The ability to use their own movement in contact with other people for the development of their own movement competence and self-efficacy.

The purpose of Kinaesthetics training is to improve nurses' own interaction and movement competence, which is an essential prerequisite for supporting older peoples' movement and active participation while assisting them in their daily activities [47]. Kinaesthetics training is not only a technique or a method to learn about the right handling or the correct posture. Moreover, nurses get the fundamental understanding of kinaesthetic interaction and human movement which support the individual assistance of older people as well as nurses' creativity (49, 46, 47). In Kinaesthetics training, nurses initially learn to understand each dimension (see Table 1) with regard to their own body.

1. They learn the six Kinaesthetics dimensions and their meaning for care situations.
2. They learn and understand the relationship between the quality of their own movement and the participation of older people in activity.

3. They develop first ideas on how to take care of their own health development and how to support older people participation and self-efficacy.

Learning methods are as follows:

1. Individual experience of own movement,
2. Partner experience (perception of differences in their own movement while interacting with another human being),
3. Using learned content and experiences in practice situations,
4. Planning and implementing of own learning process in nursing practice,
5. Documentation and evaluation of own learning process

The understanding developed from studying the dimensions of kinaesthetics and filtering them into relevant learning methods can be utilised to define the system requirements.

2.3 Motor learning & its stages

Motor learning has been defined as a "set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for skilled behaviour." As discussed previously in the motivation section that motor skills learning is a fundamental part of various domains. Hence, they vary widely in type and complexity as per the domain we are considering. For example, learning motor movement for dancing relates to the overall accuracy of the visual appearance of the dance composition [2]. However, in the domains such as music learning and medical training, there are certain intricate steps of the procedures that need to be performed with a certain level of individual accuracy [10]. According to Gabriel Wulf no matter how broadly these motor skills vary in type and complexity, the learning process that individuals go through when acquiring various motor skills is similar [17]. According to his theory of human kinetics, every learning process comprises three stages (or phases) proposed by Paul Fitts [19] namely: cognitive stage, associative stage, and autonomous stage (Table 2).

Stages of Learning	Characteristics	Attentional Demands
Cognitive (Verbal)	- Movements are slow, inconsistent, and inefficient - Considerable cognitive activity is required	Large parts of the movement are controlled consciously
Associative	- Movements are more fluid, reliable, and efficient - Less cognitive activity is required	Some parts of the movement are controlled consciously, some automatically
Autonomous (Motor)	- Movements are accurate, consistent, and efficient - Little or no cognitive activity is required	Movement is largely controlled automatically

Table 2: Stages of Learning [19]

1. Cognitive Stage

During this initial stage of motor skill learning, the learner tries to develop an overall understanding of the skill by figuring out what the objective is and what is needed to be done. There is significant cognitive activity involved in this stage because of which the movements are relatively controlled in a conscious manner [17]. This stage sometimes also involves learners using (overt or covert) self-talk and hence is also known as the "verbal stage" [20]. Self-talk is considered as the way one talks to oneself and sometimes also be unaware about doing so. During this stage, learners often try out various strategies to determine which one works or do not work in bringing them closer to the ideal movement. This phase requires a step-by-step procedure of the movement which requires the learner's attentional capacity. The result of using consciously controlled stage is that the movement is relatively slow, abrupt, and inefficient and that performance is rather inconsistent [17].

2. Associative Stage

After observing and acquiring the basic movement patterns in the first stage, the movements are refined in the second, or associative stage. This phase involves minute adjustments to the movements where the learner focuses on "how to do" a movement rather than "what to do". This stage facilitates a reliable outcome of the movements because of the consistent practicing of the same. Proprioceptive cues play a key role during this stage while the visual cues now become less important for the learner. This leads to reduced cognitive activity requirements [18]. Proprioceptive cues refer to the learner focusing more on how their body is moving in space and what input is being felt from their joints and muscles. With an increased focus on practising during this stage, the proprioceptive input facilitates as an auxiliary to the learner in learning the movements. There is a gradual reduction of inefficient co-contractions and the movements are more fluid and reliable [17].

3. Autonomous Stage

This is the final stage of learning in which performing motor skills becomes seamless for the learner. Producing the movement becomes quite efficient such that the skill becomes almost automatic or habitual for the learner. In this stage it's likely called as unconscious competence [20]. Apart from little to no cognitive activity requirement, this stage also requires relatively less muscular energy. This is characterised by accurate and consistent movements with few or no errors. The learner has had so much practice with a skill that it becomes "second nature" and can be performed easily with only little thinking.

These stages provide a good framework for learning motor skills and is also widely accepted as a sound pathway for cognitive development [21]. But to facilitate retention of information for the learners, it is necessary to provide them with effective feedback. The importance of feedback in Mixed Reality Displays and its essential distribution over the three learning stages of motor learning is discussed in the next chapter.

2.4 Defining the requirements

1. **Feedback** - *Support mechanisms to feed information to the learner via various senses*

According to the kinaesthetic concept system, sensory feedback is a fundamental way how humans learn and experience bodily movement. These feedbacks are important for the learning process and sometimes also act as a communication channel [6][16]. During the kinaesthetic training programs in the institutions, the medical students are taught and supervised by an expert. During these training programs, another fellow student acts as a patient for learning purposes. In such an educational setting, the expert acts as terminal feedback and the human body helps to gauge the sensory feedback during patient transfers [43][44]. However, in a virtual system, this should be adequately facilitated as the patient and an expert won't necessarily be available. Some studies have already discussed the future potential of multimodal feedback for such systems in the future [10]. And that the systems could be inspired by teachers' present practices as well. Hence realisation of various sensory feedback mechanisms is a key requirement of such a system. These feedback modalities are discussed in detail in the next chapter and later will be used for analysing related work.

2. **Demonstration/Instructions** - *Aid the learner with essential timely movement directions*

As mentioned earlier in the first requirement, during the academic training of nurses - the students are guided and supervised by an expert in kinaesthetics. The students gather information by reading books during their curriculum or by observing experts perform movements during the training workshops. Hence it is essential for our system to support learning by providing necessary instructions to the user. These can range from showing a demonstration of the kinaesthetics movements to providing instructions for them to carry out movements in a proper fashion.

3. **Perspective** - *Assist the leaner with varying viewpoints whenever necessary*

While learning a movement in real-life, we - humans perceive everything from our own viewpoint. However, in a digital/virtual learning system, different viewpoints can be facilitated from which a user can experience their environment. For learning kinaesthetics movement, it is essential that we provide users with an opportunity to explore their environment from their own perspective. Previous research already found benefits from investigating an egocentric visual perspective for motion training (e.g., [39]) This is essential so that the users learn the movements as they would in real-world training. This would also later help the students to transfer their learnings into real-world. The aspects of 'transfer of learning' will be discussed in a sub-section of the next chapter.

4. **Stages of learning** - *Be aware of the stage of the learner for the movement*

One of the important requirements to consider apart from those derived from kinaesthetics is also how humans learn movements. These requirements are mapped collectively under categories essential to have a supporting system for training nurses in patient transfers(Table 3).

Requirement	*Explanation*
Feedback (Real-time)	*Support mechanisms to feed information to the learner via various senses*
Feedback (Long term Statistics)	*Support the learner to later reflect on their training*
Demonstration/ Instructions	*Aid the learner with essential timely movement directions*
Perspective	*Assist the leaner with varying viewpoints whenever necessary*
Scope	*Cover the essential bodily scope so as to provide relevant data to the learner*
Stages of learning	*Be aware about the stage of the learner for the movement*

Table 3: Requirements for a support system to learn patient transfers

The learnings from the two fundamentals - kinaesthetics & stages of motor learning have helped us to develop a blueprint that our system could be built according to. The next chapter briefly describes Mixed Reality and explores the feedbacks in detail with respect to MR display and motor learning.

3. Providing Feedback with Mixed Reality Displays

This chapter covers a brief theory which explains mixed reality in the first section. Then we try to understand how the transfer of learning takes place while learning new movements. Further, we shall look into detail how feedback and motor learning are closely related when it comes to the transfer of learning. And in the latter part, how various feedback mechanisms can be realised in collaboration with mixed reality display technologies. Lastly, these feedback modalities will be mapped to relevant stages of learning.

3.1 Mixed Reality

After highlighting the need and requirements of developing a system for nurses in order to learn and train by themselves, it is necessary to understand some technicalities associated with it. Initially, we can briefly take a look at the term Mixed Reality and some of its definitions. Mixed Reality can be defined as the merging of real and virtual worlds to produce new environments where physical and digital objects co-exist and interact in real-time. In 1994, Milgram and Kishino proposed a continuum (Figure 3) which characterised MR as follows:

> MR involves the merging of real and virtual worlds somewhere along the "virtuality continuum" which connects completely real environments to completely virtual ones.

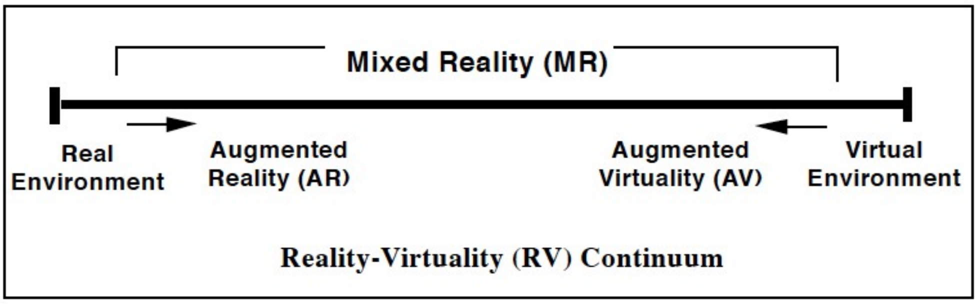

Figure 3: The Mixed Reality continuum.

As the system will be meant for motor skills learning and particularly in medical domain for nurses, it is required to review some theories apart from Human-Computer-Interaction as well.

3.2 Motor movements learning and transfer

Before we go further in this section, it is necessary to understand what do we mean by *'transfer'* in this context. Earlier, in the introduction we described 'transferring of patients' as a part of kinaesthetics movements. However, here we want to discuss the factors related to the transferability of motor movement skills learned as a digital interaction into the the physical world interaction. It is important to address transferability so as to understand how the learning in the Mixed Reality digital environment can be enhanced while keeping it effective and naturally close to the physical learning experience of the users (nurses).

> *"The improvement of performances in the physical interaction due to the training with the digital interaction is considered as transfer effect. The amplitude of transfer is taken as an objective quantification of the sensory-motor similarity of the digital interaction with physical interaction"* [22].

The previous works in motor learning ([9, 21]) point in a direction that the extent to which the transfer of motor learning happens (e.g. performance improvement, skill retention, movement recall) might be a corollary to the sensory-motor similarity between the digital and physical interactions. In other words, slope of transfer should be observed as a function of degree of sensory-motor similarity between the different interactions. This can mean two things for our envisioned system:

1. **For learning/training:** The digital interactions should have effective feedback which are analogous to an expert guiding a learner during movement training. For example: Augmented visual-audio feedback to support sensorimotor synchronisation practise.

2. **For supporting/enhancing realism:** Feedback systems are unique in their ability to recreate realistic digital experiences. For example: Haptic system to dynamically render physical representations, or audio and visual feedbacks to render emotions and dynamic reactions.

Motor movements learning in our case of Kinaesthetics trainings among nurses deals with acquiring the skills with subtle modifications and that too with precision. The term *skills* can cover a range from effectively recalling the movement to performing it as close to the ideal movement. We also have to consider the interaction with real or digital objects through direct or indirect body actions: learned abilities that involved a specific control of the body via sensory-motor loops to achieve a specific task. AR-Arm is one of the examples of an implemented system for upper-limb motor control and learning [26].

Past experiences of the user with a certain type of technology or familiarity with a digital interaction affects learning and the effective positive transfer motor skills into reality. Also, no familiarity with certain technologies can greatly hinder the motor movement learning process. These hinderances are termed as *interferences* [27]. The transfer of skill by facilitating similarity in the digital and physical (real-world) interactions for our users (nurses) can be used an an objective evaluation later at the sensory-motor level.

To facilitate an effective natural learning experience to the user as mentioned above one of the techniques we can use is *feedback.*

3.3 Feedback and transfer of learning

In HCI research, feedback and transfer of learning are considered to be one of the crucially important parts [22]. Specifically in regards to motor sensory skills, learning is considered to be “improvement, through practice” [23]. Interactions with various systems create different sensory-motor experiences for the users which can be termed as more or less ‘natural’ as to what they were expecting. Making these digital interactions similar to the physical interactions is considered important so as to transfer the digitally learnt motor movements effectively in physical (real) world environment. Before exploring various types of feedbacks at the three stages of learning, let's look into the aspect of transferring of skills in association to learning motor movements.

3.4 Feedbacks and their applications

Feedback in general can be defined as an information received in response to a task performed. When it comes to interactions mainly in the field of HCI, we can classify feedback based on its relational trigger.

> *Inherent feedback "is information provided as a natural consequence of making an action". In contrast, augmented feedback is external feedback artificially presented to the user based on "information from the measured performance outcome"* [29].

The aim of motor learning is to enhance the complex movements (re-)learning by optimising instructions and feedbacks. To train a specific motor movement, instructors use specific modalities to tailor the learning of the motor task. For instance, instead of showing them corrections they move the learner through set-by-step movements of the motor task. Analogous to this approach, in current Mixed Reality technologies we can provide augmented feedback while addressing different modalities. The means by which these different feedback modalities can be addressed are: vision (screens, head-mounted displays), hearing (speakers, headphones), haptics (robots, vibrotactile actuators), or a combination of them [28].

Augmented feedback can also be a function in relation to time. Such strategies of providing feedback can be categorised according to when the feedback was provided with respect to the motor task.

1. **Concurrent feedback:** Also known as real-time feedback, is provided during the execution of the motor task or when the movement is being performed.
2. **Terminal feedback:** Is provided after the completion/execution of motor task. This can be beneficial for reflection.

These interaction feedback technique segregations discussed above are associated with physicality and motor movement learning. It is critical to consider and discuss these since we are designing a motor movement learning system using emerging MR technologies. Augmented feedback is widely accepted as beneficial to motor learning. However it also largely depends on the combination of the motor task complexity and the type of feedback modality applied (Fig. 4) [28].

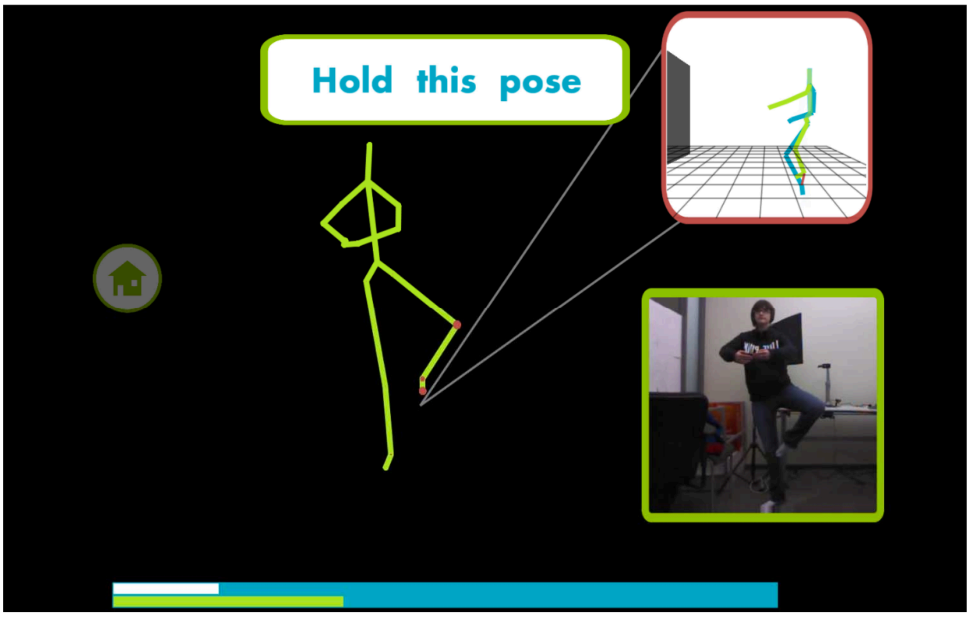

Figure 4: Real-time feedback shown to the learner in the YouMove movement training system [1].

The kinaesthetics movements for which the nurses are to be trained are complex. However, the macro motor task will be segregated into multiple micro-movements(steps). These individual step-movements are in-turn addressed on various levels according to the stages of learning. Hence, it is necessary to understand the various feedback modalities and their application with respect to various learning stage.

Feedback modalities

We, as humans cognise our surrounding environment with multiple senses simultaneously. This implies that real-world feedback is multimodal in nature and virtual environment must incorporate these to give a sense of realism. To simulate these senses in a virtual system different feedback modalities and actuators have to be employed. In further sections we will briefly describe modalities and their relevant attributes for motion guidance.

1. Visual feedback

Visual feedback is often considered as the dominant form of feedback and can be used to depict varied types of information to the user. Systems like YouMove [1] use it as an augmented awareness for correct posture (e.g., emphasised body parts movements). Also, on other hand visuals provide users with objective observation of their motion (errors) and along with superimposed potential target placements in systems like Onebody [5] and Physio@Home [31].

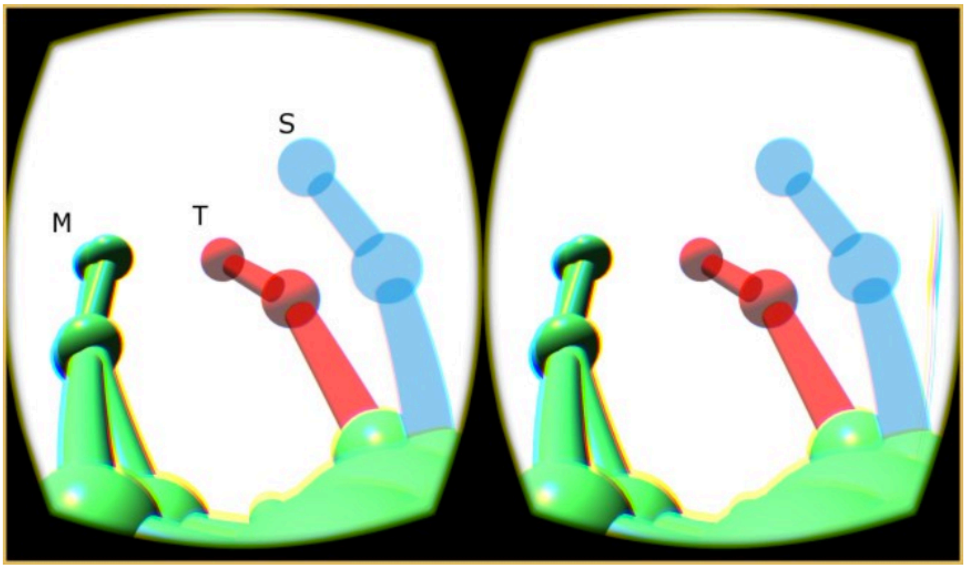

Figure 5: OneBody: Coach limbs(S) in blue, correct limb in green(M), mistaken limb in red(T) [5]

2. Auditory feedback

During one-to-one movement learning, vocal instructions proves adequate if the user's visuals are engaged at a particular instance. When it comes to auditory feedback, spatial audio proves useful to communicate 3D positions or direction in virtual environments. However, non-spatial audio can also be used to deliver essential guidance to the user during the task. Thus, audio feedback is appropriate for providing training and feedback for movements since it does not rely on users being able to see the screen. It can be used to

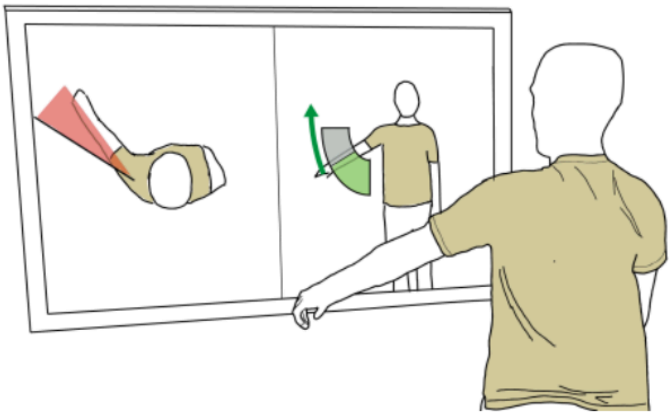

Figure 6: Overlaid visualisations in personal Physiotherapy exercise learning session [31]

express temporal constraints, and has potential applications in conveying errors. Concurrent auditory feedback has been successfully applied in motor learning. Sound modulation has already been successfully applied in a movement synchronisation task [32]. This depicts that music can be used to provide feedback in a more pleasant way. Auditory feedback may hinder the processing of other sensory afferences to a lesser extent as compared to the visual feedback. Therefore it can still be used to calibrate the motor program like sparse visual information.

3. Haptic feedback

Any form of interaction that involves touch or is composed of skin sensations can be considered as *Haptics*. In terms of HCI, a haptics interface is a system that allows human to interact with computer using bodily sensations. Haptic interactions has a significant impact on the development and motor learning of human infants, when their visual senses are not developed fully. This is possible because of the bi-directional property of the haptic sense as it not only helps us to interact with the world around us but also perceive these interactions [33].

Since haptic sensation is such an important aspect of a human body for perceiving its environment and learning from it, it is necessary to address feedback via this channel in a virtual system. Haptic feedback is generally divided into two different classes: Tacticle and Kinesthetic. At a higher level, these two classes can be differentiated as:

Kinesthetic: The things you feel from sensors in your muscles, joints, tendons. Weight, stretch, joint angles of your arm, hand, wrist, fingers, etc. Imagine holding a coffee-mug in your hand. Kinesthetic feedback tells your brain the approximate size of the mug, its weight, and how you are holding it relative to your body.

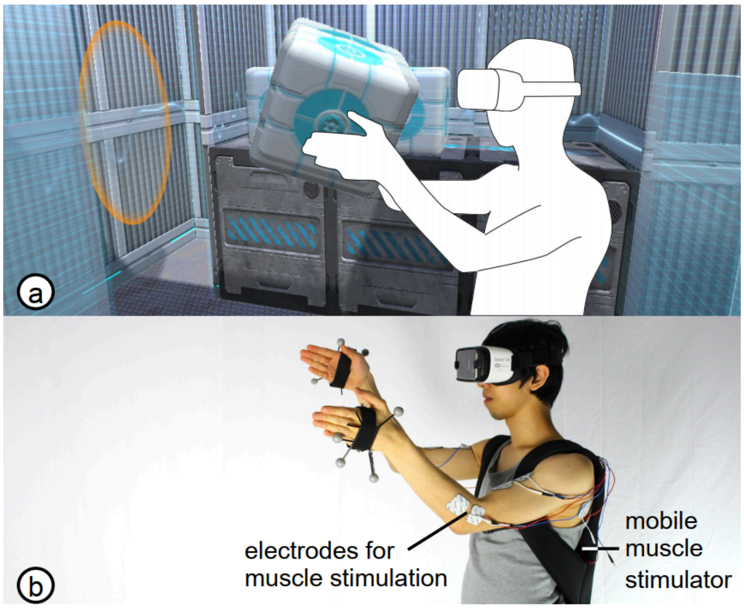

Figure 7: (a) As this user lifts a virtual cube, the system lets the user feel the weight and resistance of the cube. (b) It is implemented by by actuating the user's opposing muscles using electrical muscle stimulation [34]

Tactile: The things you feel in your 'fingers' etc., or on the surface. The tissue (for example in your fingers), has a number of different sensors embedded in the skin and right underneath it. They allow your brain to feel things such as vibration, pressure, touch, texture etc.

Haptic Feedback is a combination of both Tactile and Kinesthetic feedback.

The haptic sense complements the sense of vision, because it allows the obtaining of information from other physical characteristics. Such haptic interactions are known to speed reaction time and reduce hand–eye coordination errors for computer-related tasks [33]. Also, it can enhance interactive systems' realism through more natural interaction with objects and the environment. Pedro et al. (2017) for example, used muscle stimulators to let user feel the weight and the resistance of the cube (Fig. 7).

As illustrated by Luo et al. [35], delivering tactile warnings using tactors can be a good alternative for correcting wrong posture in Yoga training. This covers the stationary part in movement training. However, Salvado et al. [36] augmented the human arm with a wearable sleeve containing bending sensors and multiple actuators, and corrected arm postures by using different vibrotactile patterns in order to guide athletes or patients arm movements during remote rehabilitation. And also, it has been observed that vibrotactile instructions helps in achieving high recognition accuracy and quicker user response than instructions presented over audio channel [37]. We have already discussed previously that transfer of motor learning skills is directly influenced by the similarities in the digital and physical interactions. Hence, bodily sensations delivered by haptics can be a key to enhancing the learning of complex movements in the virtual world. These works provide a necessary foundation to further explore haptics in detail for movement learning for Kinaesthetics tasks.

Applying feedback - Task complexity and stage of learning

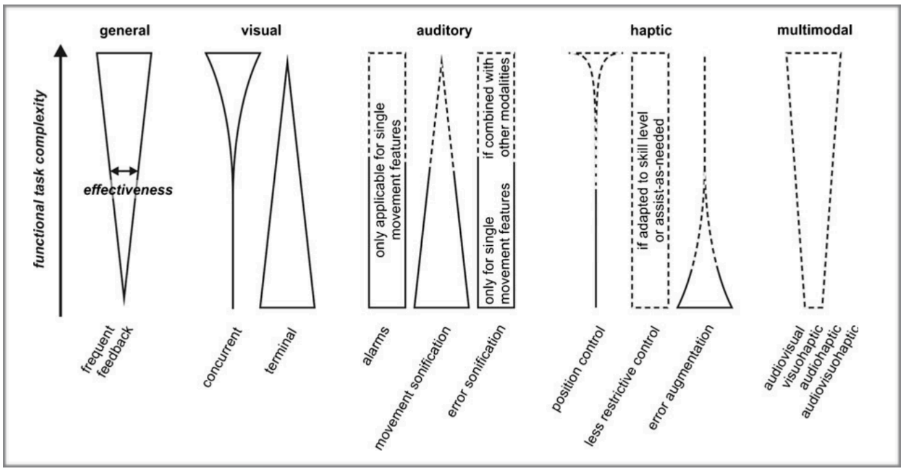

Figure 8: The figure shows the experimentally confirmed (solid) and hypothesised (dashed) effectiveness of a feedback strategy to enhance motor learning depending on functional task complexity. The broader the shape, the more effective the strategy is. [28]

The key requirement determined previously in the chapter 2 was feedback. The effectiveness of a particular feedback modality with respect to the task complexity is shown (Fig. 8). This also covers the nature of the feedback instruction that is to be provided to the user. These studied patterns can be understood so as to avoid overwhelming the leaner and thus hampering the learning process. Araullo et al. (2015) in their paper provided some initial set of guidelines for the HCI designers building interactions for motor movement learning systems. These guidelines are designed so as to support the learning and training process in accordance with Fitts' and Posner's stages of motor learning (Fig 9). The mentioned guidelines can be taken as a starting point to develop an adequate feedback for our system that will support movement learning of patient transfers.

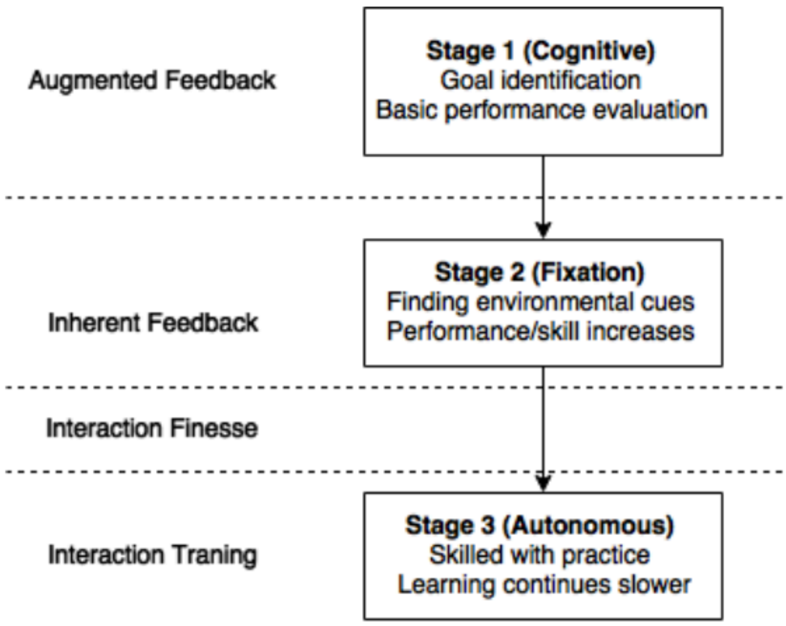

Figure 9: Feedback guidelines mapped to stages of learning

This chapter from the start helped us to gain the understanding about the technicalities associated with the system we are trying to develop. The literature assisted us in overlaying the two spheres - motor learning & type of feedback. We understood how this overlap can be applied in mixed reality. This resulted in emergence of guidelines that we can follow so as to realise the blueprint of the requirements that we derived as a conclusion of chapter 2. The upcoming chapter discusses the most relevant existing systems based on what we have achieved so far.

4. Related Work

In this chapter, we discuss previous researches that implemented and/or investigated computer-supported movement learning system(s). There have been various researchers who explored digital systems supporting surgical skills (e.g., [54]). However, when it comes to nursing-care education, there are very few systems that employ mixed reality display technologies. Most of the researched systems related to nursing care make use of common computer screens [55], which are sometimes combined with a physical manikin. Furthermore, most systems focus on the conduct of an activity related to a patient, while neglecting potential health implications for nursing care workers. Thus, several authors (e.g., [56, 57]) conclude that previous research explored only part of the potential provided by current technology. In the second section of this chapter, we summarise the essential points that are taken into consideration for our system.

4.1 Analysis of existing systems

By using data related to the learning of patient transfers as a basis, Dürr et al. [56] suggested application possibilities for mixed reality technology to support motor learning. Researchers have explored and designed computer systems that support learning movements in varied domains. We now will discuss seven of the most relevant systems in related to our requirements extracted in chapter 2 (Kinaesthetics & Motor Learning).

1. YouMove

YouMove is a system for learning full-body movements [1]. The system comprises a half-silvered mirror in which the user can see his/her reflection. The mirror is superimposed with graphical overlays to provide instructions and guidance to the users. The superimposed virtual skeleton on the user's reflection makes the user imagine the movements from a third-person perspective. The instructions provided to the user are in terms of audio cues and adaptive movement graphic overlays. This is one of the only systems which dynamically adapts the speed of guidance overlays according to the user. The important feature to be taken into consideration from this system is that along with the first two stages of motor learning, it also partially caters to the third stage. This extent of fulfilling the third stage of learning is provisioned by giving choices to the user. YouMove notably focuses on user-driven learning by providing a choice to select a stage of learning

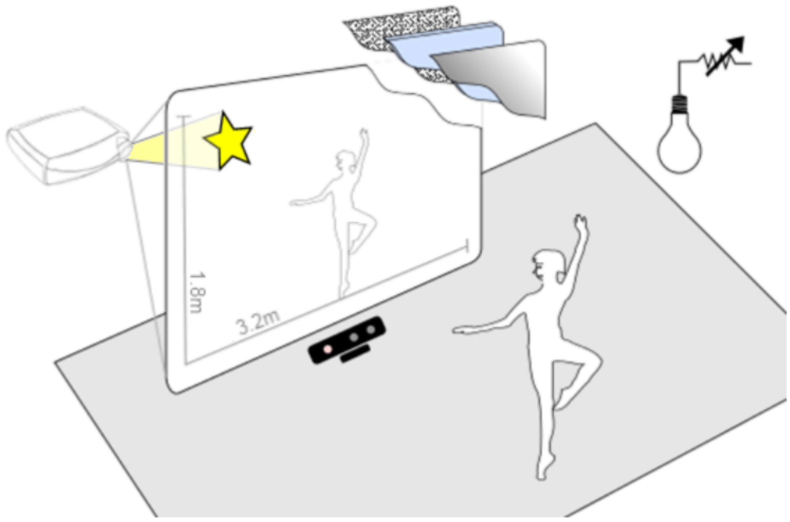

Figure 10: Overview of YouMove system design [1]

according to their preference. The system offers five stages to the learner namely: *Demonstration, Posture Guide, Movement Guide, Mirror, and On Your Own.* The stages progressively introduce the movement to the trainee, and gradually reduce their reliance on guidance and feedback. Each stage presents the user with unique challenges and a different context to perform the movement, reducing the negative impact of the specificity of learning. This means learners with varying skill levels and preferences can dictate their training needs. This could be essential for our envisioned system as well since we plan on building it on basis of stages of learning by Paul Fitts. When observed closely, YouMove system inherently includes the stages of learning distributed in a five-part learning process. YouMove supports mainly terminal feedback in form of a summary. During this feedback summary, the user is provided with keyframes and can watch the aggregated errors in each frame. While the feedback is shown the user can still see their reflection. This still helps the user to understand a particular frame posture by again performing it without any system assistance. The learner can also see their own video compared to an expert's video while performing the same movement. The video can be used to reflect on what was incorrect. The system uses the Root Mean Square Error (RMSE) as a measure of learning, which is limiting. However, some of these features from this system can prove to be beneficial for our system to support the learning of patient transfers.

2. Physio@Home

Physio@Home guides people through pre-recorded physiotherapy exercises using realtime visual guides and multi-camera views [31]. This work domain closely relates to what should potentially be addressed by our system for learning patient transfers as well. Physiotherapy exercises also require a level of correctness to avoid any injuries. Usually, the patients are also assisted/trained by an expert - physiotherapist. However, after some time the patient has to perform these exercises by themselves. The system supports multiple camera views for the user - Top view and front view of the user's arm movement. This multi-view approach helps in depth-perception when the movement is perpendicular to the camera. The visualisations shown in both the view are generated correctly because of an integrated tracking mechanism. Physio@Home addresses the guidance and feedback requirements quite extensively. For displaying the exercise's movement characteristics, the system uses something defined by them as a *Wedge visualisation*. This visualisation acts as both guidance and real-time feedback for the learner. The wedge visualisation is composed of a movement arc, a directional arrow, the nearest arm, and a top-down angle (Figure 11). This implementation of a real-time visual guidance and feedback can prove beneficial for our scenarios of learning patient transfers.

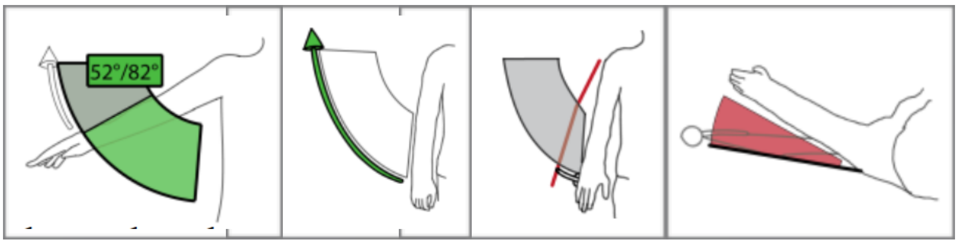

Figure 11: Wedge visualisation in Physio@home [31]

As terminal feedback, the system provides the learner with an option to playback their recording as well as an error metric. The error metric provided at the completion of the exercise is generated by comparing the learner's movement with the pre-recorded movement. Both the movement are scaled appropriately and a mean Euclidean distance is used to generate the error ratings.

3. Stylo and Handifact

Stylo-Handifact is a spatial user-interface which comprises of a haptic device [59]. The device is attached to the user's hand along with a head-mounted display(HMD) which can visualise a virtual arm for the user. The system is designed to aid posture training applications by providing visuo-haptic feedback. This system uses sensory cues as stimuli that activate the different senses e.g. audition, vision, somatosensation, olfaction, etc. Sensory cue integration refers to whether or not the brain will "integrate" multiple cues. i. e., whether these cues will be judged to originate from the same source, and thus whether the sensory attributes of each cue will be estimated together (cue integration) or independently (cue segregation). The system also helps us to understand how the virtual world visual offset can be

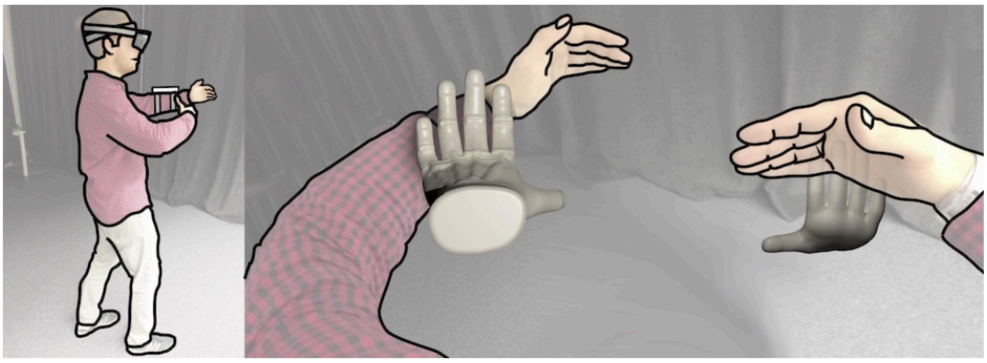

Figure 12: Illustration of Stylo/Handifact in an interactive training system displaying motion corrections to the practitioner [59]

dealt with. Thus leading to a more realistic synchronisation between the location of the instructions delivered to the learner in virtual world. The two studies conducted by the authors of the system prove that haptic nudge along with the visual support can prove beneficial in learning of new movements and their retention over time. It also shows that performance time improves when the user is delivered with a haptic sensation along with visual instruction. Although completion time is provided as a terminal feedback to the user, it is not essential to reflect on the learning. The user cannot observe the timeline to understand where he/she went wrong during the process. The main takeaway from this system is the learnings related to the provision of haptics and its extent.

4. AR-Arm

AR-Arm system provides an egocentric guidance for arms movement with a video see-through HMD[26]. It allows the learner to follow the coach's movement from the same view. The system provides augmented visualisation by overlapping coach and learner body in real-time. While performing the movements, concurrent feedback is provided to the learner so as make subtle improvements while the movement is being performed. It not only tracks the motion of the learner's arms but also considers the rotation of arms while determining the accuracy of the movement. This is an essential takeaway for our system to consider different dimensions of movements while learning patient transfer movements.

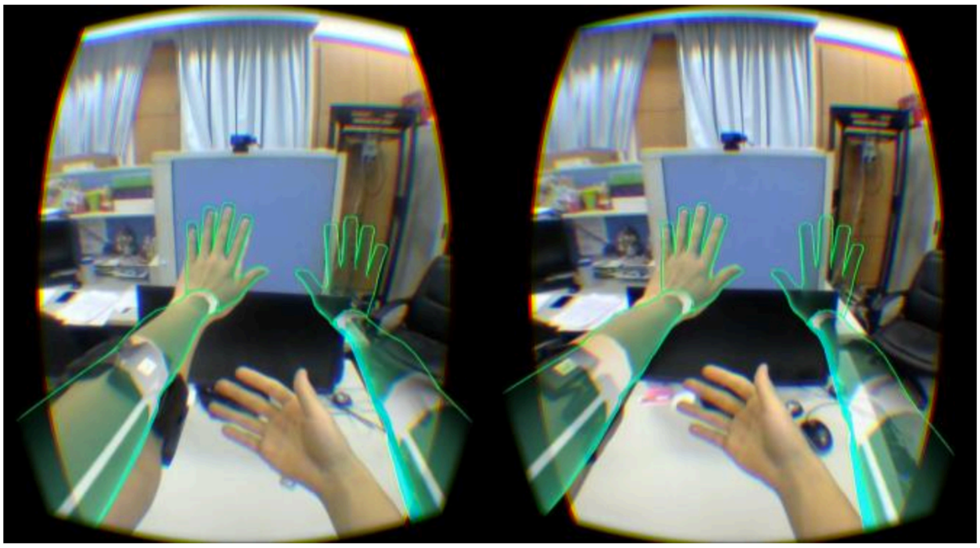

Figure 13: The first-person views of user using AR-Arm, where the semitransparent arms are used as egocentric hints to guide the user's arm movement[26]

5. EXILE: Experience based Interactive Learning Environment

The motivation behind developing Exile was the hyper-aged society of Japan. This system was built for promoting the health of the elderly people not necessarily dependent on the geriatric nurses[60]. However, the important factor which this system considers is the complexity of the movement and focus on the safety of one performing it. Though the overall goal in the EXILE system differs from ours, the intricacies of system implementation overlap with the one we are trying to build. The system uses tracking for the whole scope of the body. The feedback provided to the user is based on skeleton overlap of the instructor's recording to that of the learner's. Visual feedback in real-time is provided by thresholding. This

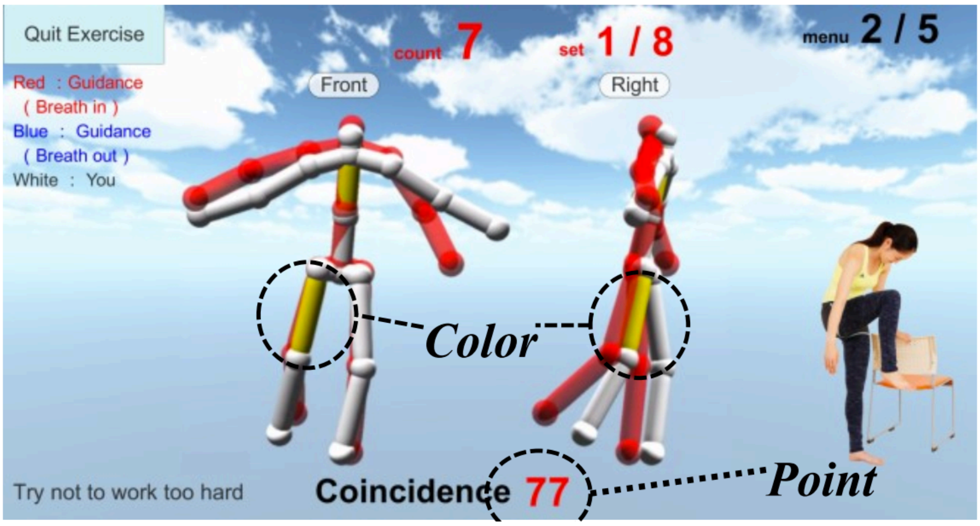

Figure 14: Screenshot of the EXILE training system[60]

means if the angle of the joint during the movement exceeds a certain limit, the system warns the learner of the imperfection in their movement. This particular part of implementation can be used as a basis for full body tracking in our envisioned system. This would be beneficial for nurses learning movements, as the MSDs such as lower back pains occur due to incorrect postures.

6. Onebody: Remote Posture Guidance System

Onebody is a virtual reality system for remote posture guidance using first-person perspective [5]. The system utilises the Microsoft Kinect sensor for skeletal tracking of an instructor and a student, who are not collocated. By overlaying the virtual avatars of the instructor and the student (Fig. 15), the system creates a visualisation of first-person perspective to deliver movement instructions. The system generates an error value when a particular movement is completed and then compares it to the pre-recorded movement of the instructor. In later studies conducted by the authors, it was

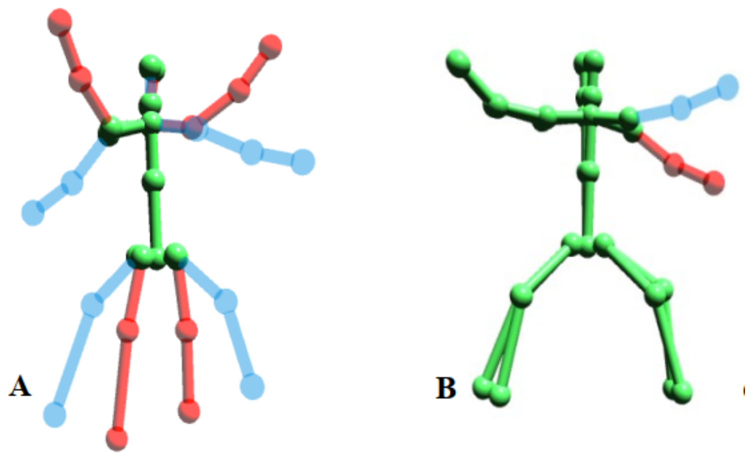

Figure 15: Overlapping avatars [5]

found that there was an overall improvement in the accuracy of upper limb movements by the learner. The system shows upper limb visualisation form the trainer's perspective. However, the learner can also observe the whole body movement being mirrored in front of them during the whole process. This also helps the learner to understand movement dynamics from alternative angles which is a crucial implementation takeaway for our envisioned system.

7. Naviarm: Augmenting the Learning of Motor Skills

Naviarm is a haptic assistance system for the augmented learning of motor skills [61]. It doesn't use prerecorded video files but takes a different approach to learning. The system uses information feedback via haptic interfaces to accelerate the motor learning process. It is a backpack styled robotic arm system which focuses on upper body movements. The robotic arms are characterised by 7 degrees of freedom for each arm. The system has pre-recorded movement which can be replayed mechanically by the robotic arms to guide the user. The robotic arms act as assistance and provide some resistance if the movement being performed by the user is incorrect. This system is important from the perspective that it discussed the extent to which haptic feedback and drift corrections should be provided to the learner. It explored how a sensation can be delivered by providing resistance to the user movements. This could be beneficial for our system so as to provide haptic feedback in a controlled manner. The learnings acquired

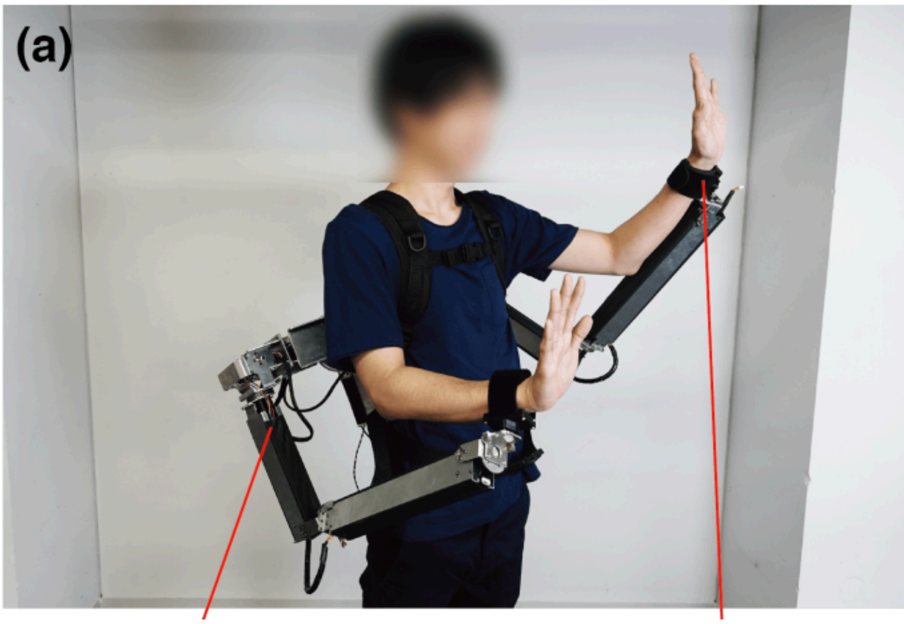

Figure 16: A system overview of the wearable haptic guidance system called Naviarm [61]

from studying this system explain during which stages of learning haptics are essential and how or when they should be delivered to the user.

4.2 Summary of take-aways

After covering the essentials from the existing system in the previous section, this section summarises the take-aways in a comprehensible manner. The gist of the summary can be referenced in table 4. The highlighted parts in green (in table 4) are the important take-aways we would be considering for our system conceptualisation.

Supported perspective

The systems like AR-Arm [26], stylo-handifact [59], Just follow me [39] helps us to understand the importance of an egocentric perspective. The studies later covered by the authors of these systems showed promising retention of learning and improvements in accuracy. The first person view to dive-into the trainer's shoes is an important factor while learning the movements. However, delivering certain kinds of feedback from a perspective of third-person could also prove useful as demonstrated by YouMove and Physio@Home systems. We would primarily focus on the first-person view for our system with an overlap of third-person for certain required learning stages.

Bodily scope

Most of the systems we studied have mostly focused on the upper body movement support. However, systems like YouMove [1], EXILE [60], and Onebody [5] have made us realise that for the learner to gain an overall understanding of the movement it is important to track the whole body of the user. This is also important from the kinaesthetics training perspective since understanding the environment and moving the whole body effectively is an important part. We shall also realise this later in the next chapter that apart from these systems certain studies conducted by motion tracking of care-taker nurses require us to support full-body scope. This means that apart from hand movements our system should be able to determine factors such as how the learner is standing while performing a certain movement and its intricacies.

Learning stages covered

The three stages of motor learning are cognitive, associative, and autonomous stage. Most of the systems that we have studied cover the first two stages of motor learning - the theory to which we covered in chapter 2. Except the YouMove system [1] which allows its user to enter the third stage of motor learning and practise by themselves to gain expertise. However, for us, it is essential to focus on the first two stages itself so as to limit the scope and focus of our study later. Also, covering the third stage of learning is limited by technological constraints at many levels. What we try to focus in our system which is also the underlying phenomena in the previous systems is to help the learner gain an overall understanding of the movement along with moderate accuracy.

Types and nature of feedback

The accuracy and efficiency of the movement can be delivered to the user via different feedback mechanisms. We have seen that various systems use multiple mechanisms to convey certain feedback messages to their users. When it comes to the feedback in relation to time, we would like to focus on concurrent and terminal feedbacks. Most of the systems have a feedback mechanism, as without it a system would essentially be incomplete.

However, after studying the previous work we have certain implementations that could work well in our scenario. Such as, the skeleton system from the YouMove system can be used to visualise lower body feedback for the learner. Showing error in the form of drifting away from the movement path or showing the user video playback with an overlaying skeleton at the end of their training session.

Instruction delivery

This part essentially covers what kind of feedback modality a system would use for certain types of instructions. The authors of OneBody and YouMove found in their studies that certain methods of delivering an instruction works better in certain cases. What it means is that feedback modalities and instruction delivery type to the user should be chosen carefully according to the learning stage the learner is in. While studying these systems it was essential to know which learning stages they are covering so that it gets easier for us to summarise which modality the particular system used in which case. For example: authors of YouMove system talk about using visual guidance in earlier stages of learning while moving to audio cues in later stages of learning. While stylo-handifact system talks about using the haptic nudges to a minimum and that too only in the associative stage (stage 2) of learning.

System name	Supported perspective	Bodily scope	Learning stages covered	Types of feedback	Instructio n delivery
YouMove [1]	Third person	Whole body	All three stages	- Real-time (Visual) - Terminal (Metrics & recording s)	- Audio cues - Adaptiv e visuals
Physio@H ome [31]	Third person	Upper body	Associative (stage 2)	- Real time (Visual) - Terminal (metrics & recording s)	- Visual path of movement

System name	Supported perspective	Bodily scope	Learning stages covered	Types of feedback	Instruction delivery
Stylo and Handifact [59]	First person	Upper body (Only arms)	Associative (stage 2)	- Real-time (Visual) - Terminal (Total time)	- Haptic corrections
AR-Arm [26]	First person	Upper body (Only arms)	Cognitive (stage 1)	None	- Visual hints
EXILE [60]	Third person	Whole body	Associative (stage 2)	Real-time (Visual)	None
Onebody [5]	First and Third person	Whole body	Stage 1 & 2	- Continuous real-time - Terminal (metrics)	- Visual hints for pose
Naviarm [61]	First person (Real-world)	Upper body (Only arms)	Stage 1 & 2	- Real-time (Haptics) - Terminal (Expert score)	- Physical motor steering

Table 4: Related work comparison on the basis of derived requirements

This chapter helped us to gain insights into what works and what doesn't work by analysing the systems previously implemented for movement learning. The summary of the takeaways are taken forward in the next chapter where we visualise out system in the form of a scenario. The details in the scenario are derived from the analysis of the previous works and adjusting them to fit our context of kinaesthetic-based patient transfers.

5. Outlook

In the previous chapter, we covered all the most relevant works related to motor movement learning using mixed reality display technologies. However, to design a scenario for our use-case, nursing care studies were also taken into consideration. Muckell et al. (2017) in their work, conducted an exploratory study using the body tracking system that they have created. They used 3D video feed and wearable sensors to track the body of the direct care workers so as to detect risky patient transfer behaviour. As a part of this study, they had defined 4 important risk metrics based on lifting and carrying guidelines[58]. When incorporated properly in daily practise, these guidelines help to reduce the risk of injury. The following are the metrics that can be detected as a part of our system as well to better inform the learner about their patient transfer movements.

- Detecting a wide support base
- Detecting squat
- Detecting good posture(upright stance)
- Detecting good posture (Avoid spine twist)

The study discusses low and high-risk motions of all these metrics as shown in figure 17.

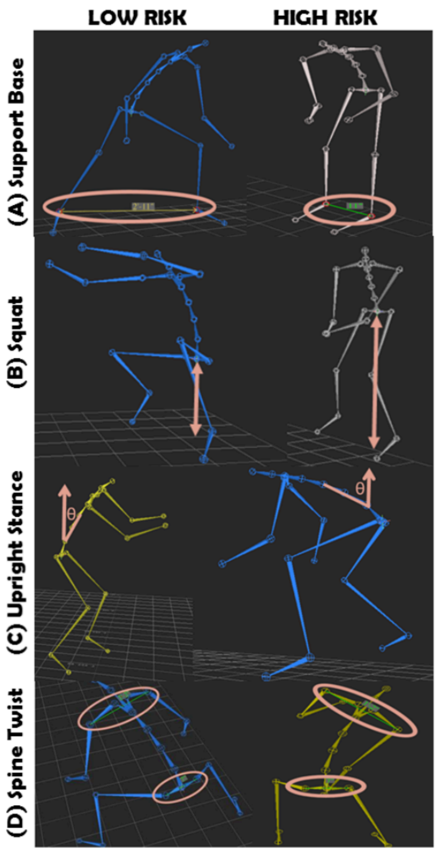

Figure 17: Low vs. high risk motions for each metric. [50]

Aside from this, previous study conducted and information gathered as a part of the ERTRAG project also mentioned some important metrics to track as a part of patient transfer movements. These include,

- Detecting the height of the bed
- Detecting bending of arms
- Detecting the direction of the movement

5.1 Storyboard

A scenario is created from the learnings of the previous sections and insights from the studies that were discussed earlier in this chapter. The scenario is explained visually in the form of a storyboard. Every frame of a storyboard is accompanied by a textual description of what is being conveyed. Some visual hints are mentioned here so that it is easy for the reader to understand the colour scheme in the storyboards.

- Real world scene has no border around the frame
- A virtual scene when the learner is wearing an HMD is depicted using a thick blue border around the frame
- Orange arrows and texts are used for labelling key elements for the reader
- Thinking bubble on the top of the avatar's head is used to convey emotions or what the learner is currently thinking

The following scenario describes certain important aspects of the system and how they could be realised in the envisioned system.

1. Bob (the system user) took part in a basic kinaesthetics course as part of his nursing-care education. However, when he tries to apply his

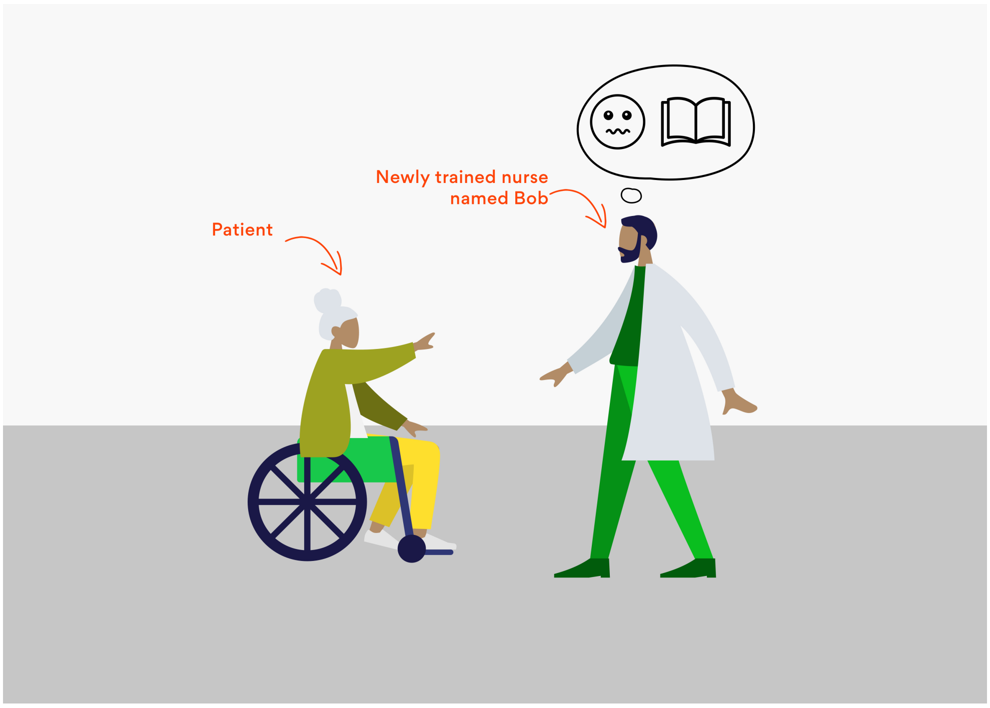

Figure 18: Storyboard introduction frame

learnings when transferring real patients, he's unsure and diffident about his movements.

2. To improve his understanding of the patient transfer movements, Bob decides to try FollowMe system which assists an individual learner to learn at their own pace. He enters a room where FollowMe system is setup and wears the head-mounted display. The system tracks the whole body of the user as it was our important take-away in bodily scope of section 4.2. This body tracking is depicted by the blue cones showing the tracking areas of the two sensors.

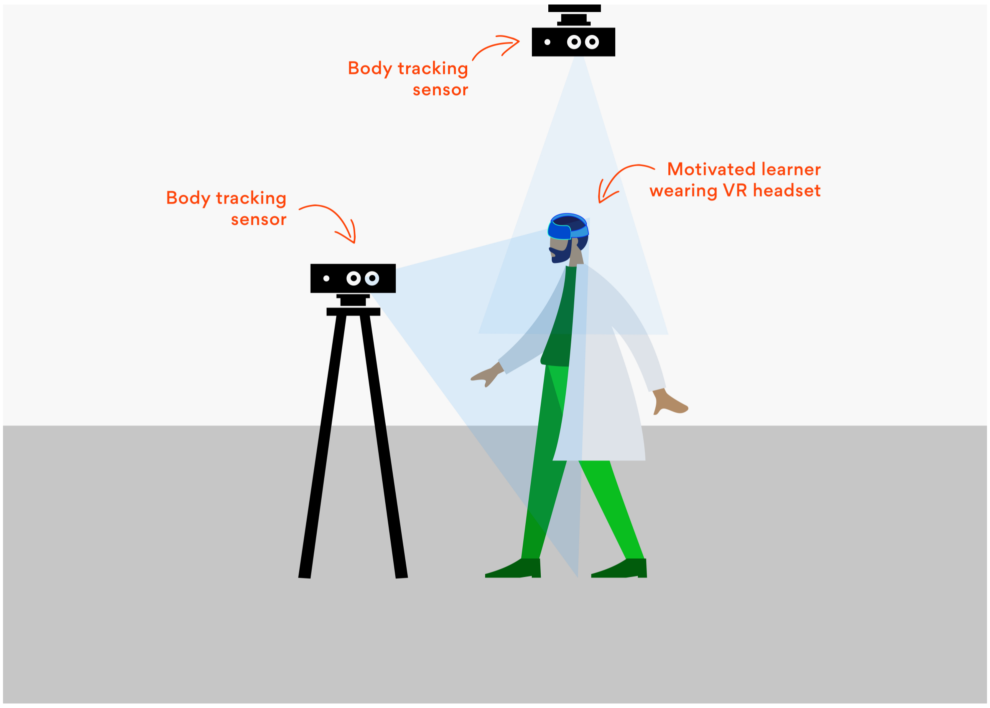

Figure 19: Storyboard - User wears the HMD and FollowMe system is initiated

3. Bob enters a virtual patient transfer scene where he can see various virtual entities such as - patient, hospital bed, wheelchair, trainer (teacher). Bob first visually understands the movement and gains an overall understanding of the essential parts of a particular patient transfer. This is a necessary stage for new learners as it was earlier described in section 2.3. New learners go through cognitive stage where they observe and skim through the movement to be performed. Our

take-away related to 'stages of learning' in section 4.2 covers the detail that the system should suffice the first two stages of motor learning.

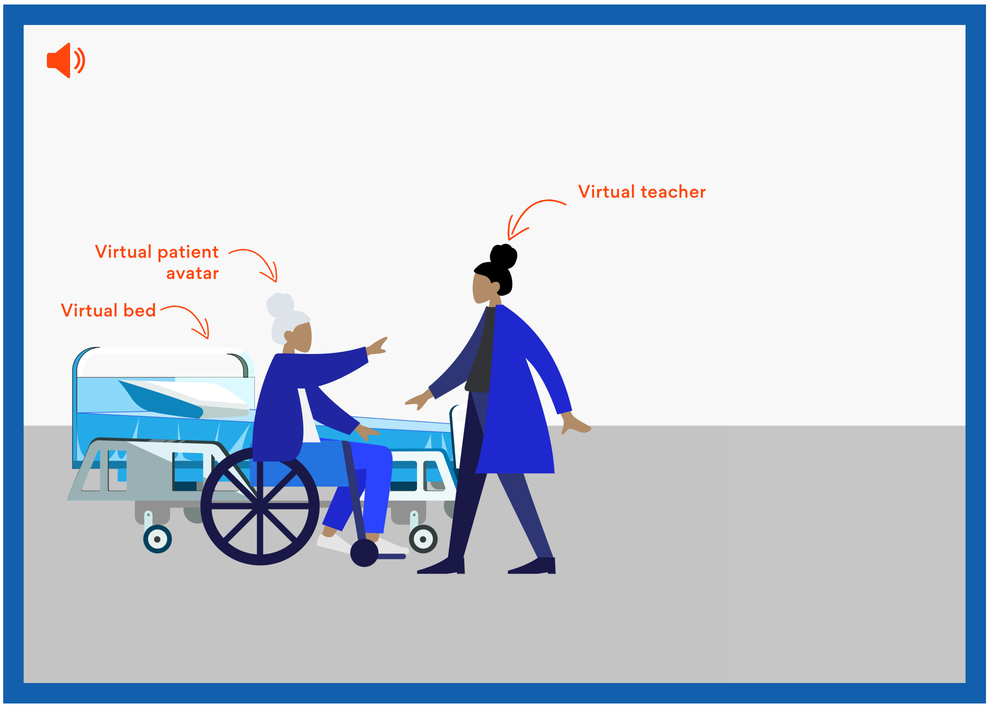

Figure 20: Storyboard - User observes a virtual patient transfer recording.

4. Bob now moves to perform the patient transfer and is guided by the system. The system guidance consists of - where he should hold the patient, how the next state of the patient would look like (green highlighted avatar). It also informs the user (Bob) about his overall body posture errors (if any). The system also shows the learner their own body skeleton as a reference image where the learner can know about any errors in their posture (Figure 21). The reference skeleton is like a mirror for the user, where the actual movements of the user are replicated so as to show any anomalies in his posture. This was an important implementation detail that was taken from the YouMove system [1] in the 'Related Work Analysis' section. This reference skeleton reflection serves the purpose of providing real-time feedback to the user when they exceed certain thresholds which might hamper their physical health.

Figure 21: Storyboard - User starts to perform the guided patient transfer

5. As Bob starts to perform the patient transfer, the system detects an error

Figure 22: Storyboard - User gets notified about the error in his posture

in the user's posture related to the angle of the lower back. The system informs the necessary information to the user through visual and audio feedback. The system also shows how this error can be resolved by making necessary changes. The error metrics shown to the user were earlier discussed in this chapter. As shown in the storyboard frame (Figure 22), the user sees that his back angle is too steep and that it can be resolved by squatting more to perform the same movement. The 'speaker' icon on the top-left indicates the audio instructions provide to the user as a part of resolving the error. This decision is informed by two learnings in our investigation - First is, that the user now is transitioning from the first to the second stage of learning [section 2.3]. This requires us to consider that visual senses of the user could be occupied with the task in hand. Thus our second learning from section 3.4 regarding feedbacks informs us to use another modality (sound in this case) to instruct the user to make appropriate adjustments.

6. Bob notes and understands the issue stated by the system. Subsequently he incorporates the necessary changes so as to fix the error and completes the movement successfully.

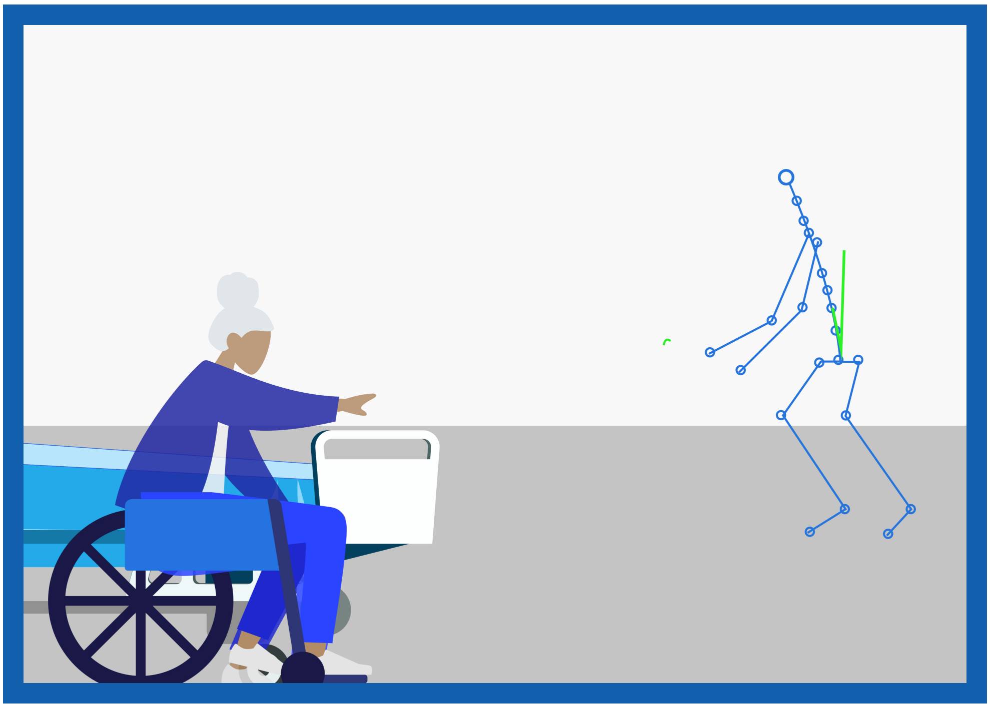

Figure 23: Storyboard - User fixes the erroneous posture and completes the movement

7. After understanding and performing the movements in the virtual world successfully, Bob can now revisit his recordings. He can compare the ideal skeleton values to his own recorded movements. This helps him to understand where he could improve and what needs to change in his professional habits. This stage is an essential derivative from our take-away regarding terminal feedback. Many previous works that we analysed incorporated some method of providing feedback at the end of the one movement session. This helped in many cases where the user can see it from a different perspective and also understand the errors with less cognitive load.

Figure 24: Storyboard - User analyses his movements recordings and reflects on his learnings

8. Bob is satisfied with his learnings and improvements over time. The next time he goes to the hospital to transfer a real patient he's more confident and can assists the patients more effectively.

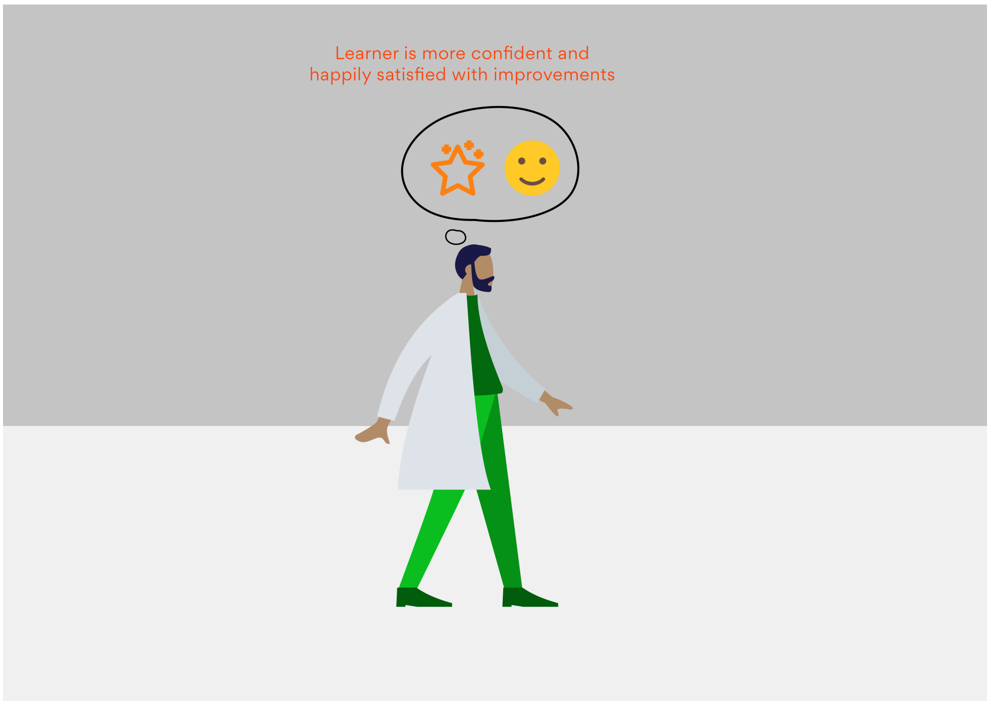

Figure 25: Storyboard - Satisfied and more confident user

This scenario which is depicted in a form of a storyboard covers some important take-aways for our system. It tries to visualise what would motivate a user to use our system, how our system would assist the user and what emotional impact the system would have on them.

5.2 Conclusion

In earlier sections, we derived the relevant requirements from the domain and the theoretical literature. In the previous section, it was investigated by what means related work targeting similar problems tried to fulfill those requirements. We realised that those systems were limited by their interface because of the technology they were using. On the other hand, some systems comprehensively tackled certain problems but lacked some key feedback points or tracking capabilities. This has helped us to gain an understanding of what a movement training system essentially requires. Moreover, we carefully adjusted those findings to our own use-case of kinaesthetics based patient-transfer. This led us to build a foundational concept using the findings discussed in the important take-aways in section

4.2 as a blueprint. The next section discusses the various modules of the system that has to be implemented thus leading to a complete system. It also discusses the current complications and how our decision-making might be adjusted to various situations.

6. Future Work

Earlier in our paper, it has been outlined why there is a need for supporting self-directed learning of patient-transfer movements. Additional to the current implementations as a part of the ERTRAG project, a user-tracking and feedback module will be developed. This module can then be integrated into the current virtual training system so as to enhance its functionalities and provide more details to the user (or learners). These details will include the various metrics that we discussed in the Outlook section and implementation styles that were illustrated as a part of the storyboard. The next step will be to implement the envisioned system. The implementation steps would include:

- Finalising a virtual reality platform combined with a feasible tracking system
- Defining threshold for various error metrics
- Implementing a joint skeleton system to translate user's movements
- Integrate the modules in the current virtual training system process

The implementation details and choice of hardware for implementation might be adjusted to the feasibility and availability because of the current COVID-19 situation.

The later stages of the project will include finalising a module for recording and logging of the metrics for conducting a user study. The data from the user study will be analysed and be used to evaluate the system which will be developed. The design of the study to be conducted can vary depending on the situation posed by COVID-19. Ideally an expert evaluation with the participants(~20) from the healthcare industry would work best. However, it poses some difficulties so as to manage various schedules and to get the availability of so many nursing care professionals. An alternative would be to conduct a heuristic evaluation by HCI experts from the department. This could also be complemented with getting feedback from the nursing care experts by sharing the video of how the system works. Worst case scenario usability tests can be performed with generic participants(less number) from outside of the domain. The available options regarding the study design has been laid out, however the decision depends on the future environmental situations. The timeline for the future work can be seen in Figure 26.

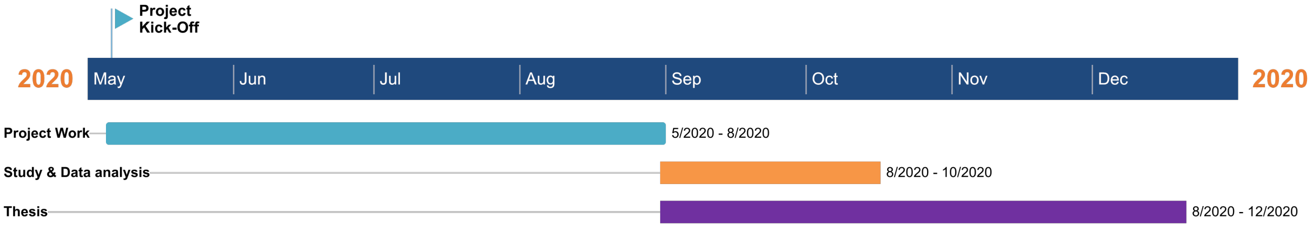

Figure 26: Schedule for future work

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