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Nadine Morkisch*, Katrin Jettkowski, Luara Ferreira dos Santos and Christian Dohle

Modelling of therapeutic action during mirror therapy

A qualitative analysis as basis for technical solutions

Abstract

Background and purpose: In patients with pathology of one limb, mirror therapy (MT) uses the mirror reflection of the unaffected side to improve function of the affected limb [1]. There is some evidence that Virtual Reality (VR) can substitute the real mirror [2]. To create a standardised VR based mirror therapy as a self-training, several steps of conceptual considerations are essential. The purpose of this project was to understand the therapeutic action of standardised MT and thus to pave the way for a partially automated VR based MT to be executed as a self-training.
Methods: A principle of motor learning, called Shaping, is anchored in two existing standardised MT protocols (BeST & BeSTEP) [3, 4]. To understand the shaping process within MT, shaping items and criteria were extracted from the protocols. Additionally, a questionnaire and participatory observation during MT sessions were performed and standardisation rules by means of documentation sheets of MT units were analysed.
Results and conclusion: The knowledge about the shaping process during conventional MT, especially in the BeST phase is currently not sufficient to derive machine learning and therefore to create an automated system at this time. Further conceptual investigations to gather this information are necessary and projected.

*Corresponding author: Nadine Morkisch, MEDIAN Klinik Berlin-Kladow/Center for Stroke Research Berlin, Charité - University Medicine Berlin, Kladower Damm 223, D-14089 Berlin, Germany, E-mail: nadine.morkisch@median-kliniken.de
Katrin Jettkowski and Christian Dohle: MEDIAN Klinik Berlin-Kladow/Center for Stroke Research Berlin, Germany; and Charité - University Medicine Berlin, Germany, E-mail: katrin.jettkowski@median-kliniken.de (K. Jettkowski); christian.dohle@median-kliniken.de (C. Dohle)
Luara Ferreira dos Santos: Chair of Industrial Automation Technology, Technische Universität Berlin, PTZ 5, Pascalstr. 8-9, D-10587 Berlin, Germany, E-mail: Luara.Santos@iwf.tu-berlin.de

1 Introduction

Patients with upper limb paresis after stroke have difficulties to carry out activities of daily living independently, which significantly influences their quality of life. For patients with initial flaccid upper limb paresis, Kwakkel and colleagues [5] reported that only 33% of the patients could be classified as independent at six months after stroke. Only 12% of patients had regained their full arm function at this time [5]. Mirror therapy (see Figure 1) is particularly suitable for patients with severe unilateral, distal paresis of the upper extremity and is a concept with high evidence in neurorehabiltation [1, 6–8]. Patients who take part in mirror therapy should have the ability to follow the therapist's requirements, be able to show either simple or complex movements with their unaffected hand and closely observe them in the mirror. [4]. Different programmes to apply mirror therapy in a standardised way for patients after stroke were published [3, 4, 9].

BeST- Berliner Spiegeltherapieprotokoll (Berlin Mirror Therapy Protocol) [4] is an evaluated instrument to standardise the execution and the documentation of mirror therapy in a one-to-one setting. The therapist requires the patient, depending on her or his level of performance, to produce one out of an individual amount of different hand and arm positions with their unaffected upper limb. At the same time, she or he instructs the patient to closely watch the mirror image of the unaffected hand. Hereinafter, this period is called *BeST phase*. A mirror therapy unit (typically 30 minutes), further called *BeST unit*, may include several BeST phases, interrupted by short breaks for rest and documentation. A period of consecutive therapy sessions in an application block, e.g. 20 BeST units, is called *BeST sequence.*

The therapist must constantly judge the patients level of performance and adapt the content of therapy, which

Figure 1: Mirror therapy with BeST.

is called *Shaping*. Thus, a specific focus in the configuration of a BeST unit is shaping [4]. On the associated standardised documentation sheet it is not only documented how the therapist structures the therapy, e.g. duration of BeST phase(s) or number of (combined) movements. It is also necessary, that the therapist observes, judges and documents how the patient could deal with the chosen content, for example, the attention of the mirror image and the level of perceived difficulty (on 3 or 4 steps scales). This reflection helps the therapist to make shaping decisions [4].

BeSTEP- Berliner Spiegeltherapie-Eigentrainings programm (Berlin self-training program for mirror therapy) [3] is a standardised mirror therapy protocol based on BeST. It was developed and evaluated for patients who are able to train independently with a single supervision per week by a therapist. In 2016, approximately 6% of all patients who participated in MT executed BeSTEP (MEDIAN Klinik Berlin-Kladow).

During inpatient rehabilitation, this self-training usually takes place in the room of the patient, whereby the patients determine the therapy time themselves. The patients receive a mirror, a booklet for information and documentation and an audio player with the movement instructions. There are various requirements for the patients, who carry out such a self-training, e.g.:

– Ability to structure the day
– Ability to prepare the treatment area, e.g. place the mirror, to position the affected arm comfortably on the table; if necessary handling the wheelchair
– Ability to handle the audio player and the booklet for information
– Ability to arrange the therapy and to prevent neither under-stress nor overstress
– Ability to document the data of the therapy unit [3]

The patients are asked to document, e.g. which title they chosen and how often they have trained with a title. In addition, they shall assess how difficult the execution was.

For several years, the use of technical systems with VR in the area of neurorehabilitation was proposed as well [10].

Some research groups who are engaged in using Virtual or Augmented Reality are already implementing mirror therapy as a part of their technical application e.g. [11, 12]. In these applications, the therapists determine and accompany the content of the therapy. A specific challenge arises when the therapy is not only supported by the technology, but rather, the technical system itself should adapt to the therapy content in an automated manner.

The purpose of this project was to understand the therapeutic action during standardised mirror therapy, how a shaping process in a self-training with VR could be created and thus, to pave the way for a partially automated self-training in a VR based MT.

2 Methods

In this conceptual process, a team of clinical experts (therapists, psychologist, and physician) asked themselves the following questions: Which actor takes over shaping within a BeST or BeSTEP unit? What is the reason for this decision? By what means the therapeutic content change? To answer these questions several steps were performed:

– Definition of terms within the shaping process - shaping items, shaping criteria, shaping actors and extraction of these out of the protocols BeST and BeSTEP.
– During eight therapy visits by the amount of given movement instructions per minute were counted by one observer by a list, to derive the instruction pace for BeSTEP and also for a future VR protocol [3].
– A questionnaire was self-created by the clinical experts to find the reasons for breaks and break-offs of the BeST unit by count of frequencies and were used by 4 therapists of 4 patients at a total of 47 BeST units.
– The clinical experts created an observation protocol with five guiding questions, e.g. "For what reasons are changes made?", "What are the consequences of the changes?". Participatory observations during MT sessions by two observers were carried out. Five patients were accompanied (reason for MT: because of stroke two Patients had a paresis on the right upper limb, one patient had a paresis on the left upper limb) with one BeST unit each. Two different therapists performed these therapies.

– 53 documentation sheets of completed BeST sequences were analysed to derive shaping decisions by therapists.

3 Results

3.1 Shaping items

Shaping items are the tools available to the therapist and/ or the patient to reduce or increase the level of difficulty. Our analysis has yielded shaping items used during BeST as shown in Table 1. Shaping items used in BeSTEP (see Table 1) are marked with *.

In this context, instruction pace was determined as intervals between the single movement instructions. In BeSTEP for a slow pace an interval of 2,5 seconds between single instructions was defined. The definition for a fast pace is a 1 second interval between the instructions [3].

Hence, BeSTEP allows a supervised, standardised self-training, but with limitations in variability of shaping items. Therefore the focus in further investigation was on the BeST shaping items.

The questionnaire of the therapists showed two most frequented reasons to give the patients a rest period or to finish the therapy period. These were the view out of the mirror or the patients showed an effort (e.g. sighing). According to the five participatory observation units, the observation was interrupted in this way. The pure observation demonstrated only vague data. No specific conclusions could be drawn about the shaping decisions of therapist, especially in the BeST phases.

3.2 Shaping criteria

The parameters which the therapists observes and judges are called shaping criteria. If the judgement of a criterion changes, the therapists must immediately make shaping decisions, based on their therapeutic knowledge and the standardisation requirements. These shaping criteria, which are involved in decision-making, are:
– Attention (on mirror reflection and movement execution)
– Vigilance
– Perceived level of difficulty
– Errors in movement execution

In summary, the analysis of the documentation sheets showed, that the therapists had followed the rules of BeST standardisation [4]. One of the rules is for example, only to increase the number of movements, if the step of the scale of attention, vigilance and level of difficulty is at 1, i.e. normal. The documentation sheets presented a problem for the further analysis. The therapists could estimate the shaping criteria only as a mean value within a BeST phase. That means shaping decisions of therapists are only shown from BeST phase to BeST phase and BeST unit to BeST unit.

3.3 Shaping actors

There are different actors in BeST. The therapists (T) as well as the patients (P) could structure the therapy content at different times. Table 1 presents the results of which BeST shaping item is changed by therapists and/ or patients and which times for these changes are applicable.

4 Discussion

With already existing knowledge how to perform standardised mirror therapy [e.g. 3, 4] and the results of this analysis, it was possible to show which shaping items are available, which criteria influence therapist' shaping decisions and

Table 1: BeST shaping items, possible actors and times.

Shaping item	Changed by shaping actor		
	During BeST phase	**Between BeST phases**	**Between BeST units**
Duration of the BeST phase	P[a], T[b]	–	–
Duration of rest*	–	P, T	–
Duration of the BeST unit*	P, T	P, T	–
Instruction pace*	T	P, T	–
Number of possible movements*	–	T	T
Use of different types of movements*	–	T	T
Use of a fixed or random order in verbal instruction	–	T	T
Changing the volume* or tone of voice	T	–	–
Instruction to imitate the movement of the therapist	T	T	T

[a]P-Patient, [b]T-Therapist.

which actors change the therapeutic content at a particular time. The documentation sheets showed a clearly recognisable structure of shaping decisions emerging from BeST phase to BeST phase. Neither the observation protocols of the participatory observation, nor the documentation sheets could sufficiently show the shaping process during the BeST phases. In order to create a standardised VR based MT protocol, it is essential to understand the shaping process on a finer time scale, i.e. within the BeST phase.

So far, it has only been possible to establish a rule-based shaping on the basis of the standardisation rules of the BeST and the experiences of the therapists. More accurate data could be collected by means of digital documentation using a smart tablet. In this case, the therapists can document the observed data (e.g. attention, level of difficulty) immediately within a BeST phase and shaping decision-making could be derived from these criteria. If the data collected with tablets were analysed and merged with already existing rule-based data, the basis will be created to establish an algorithm for shaping within standardised VR based mirror therapy. Until then, further investigations are essential.

In the future, shaping decisions for VR based MT could be based on the behavioural analysis of the patient data during the exercise, e.g. measurement of attention by finger and eye tracking. One approach to operationalise the shaping process was already reported by Hesse and co-workers in 2014 [13]. It was shown an eye and gaze-tracking system for conventional MT as an objective measurement of patients' attention to the mirror image [13]. On the basis of settings by therapists at the beginning of therapy and at supervisions, the system could make automated adaptations immediately during the course of therapy. The three pillars standardisation rules, therapeutic planning and a support by the VR system provides the possibility that patients can assume responsibility for the same shaping decisions like in BeSTEP. The greater variability of shaping and the precise individual adaptation are the advantage of a MT self-training supported by a technical solution.

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