Different explanation, less frustration?

Making explicit whether implicit motor learning strategies are feasible

Bachelor thesis

by

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Abstract

Background: *Patients who have suffered a stroke need to (re)learn motor skills in order to live independently. Cognitive deficits can make the understanding of movement instructions during rehabilitation very tough. In the sport domain, analogy learning has been shown to facilitate motor learning without the need for providing explicit, verbal rules. There may therefore be clinical utility in using analogies in the rehabilitation of stroke patients who may have cognitive deficits.*
Aim: *The aim of this study is 1) to assess the feasibility and utility of developing personalized analogies to improve walking performance in long-term stroke survivors and 2) to explore potential benefits in subsequent walking performance.*
Methods: *Three males aged 87, 67 and 70 who were 6, 1 and 3 years post-stroke, respectively, with a different walking deficit were included. A personalized analogy targeted at improving walking was designed with the help of each participant (e.g. one participant worked on an improved swing phase via a "kick the ball" analogy). During a 3-week intervention period, the personalized analogy was practiced once weekly under supervision and daily at home. To assess feasibility a questionnaire was used following the intervention. Potential effects on walking performance were assessed using the 10 Meter Walking Test (MWT) and the Numeric Rating Scale (NRS).*
Results: *A personalized "walking" analogy was established for each participant. A mean of 69.5 % was scored positively on the quantitative part of the feasibility questionnaire. A 0.137 m/s (16%) mean improvement for the 10MWT was achieved after intervention. No difference in NRS-scores were found.*
Conclusion: *Developing successful personalized analogies is a creative and challenging process. This study identified several factors that may influence the possibility of creating and developing successful analogies (e.g. the ability to visualise and the importance of a meaningful analogy).*

Samenvatting

Achtergrond:. *Patiënten die een beroerte hebben gehad moeten vaak motorische vaardigheden (her)leren om zelfstandig te kunnen functioneren. Cognitieve beperkingen kunnen het begrip van instructies tijdens het revalidatieproces bemoeilijken. In de sportwereld lijkt analogie leren motorische leerprocessen te ondersteunen zonder het gebruik van expliciete, verbale instructies. Hierdoor lijkt het zinvol om analogie leren toe te passen in de revalidatie bij mensen die een beroerte hebben gehad die cognitieve beperkingen kunnen ervaren.*

Doel: *Het doel van deze studie is 1) om te onderzoeken hoe hanteerbaar en uitvoerbaar het ontwikkelen van persoonlijke analogieën is voor het verbeteren van lopen bij mensen die een beroerte hebben gehad, en 2) om mogelijke verbeteringen in het lopen te constateren.*

Methode: *Drie mannen van 87,76 en 70 jaar, respectievelijk 6,3 en 1 jaar na hun beroerte, met verscheidene loopproblemen werden geïncludeerd. Een persoonlijke analogie, gericht op het verbeteren van het looppatroon, werd voor iedere participant ontwikkeld (een voorbeeld van analogie voor het bevorderen van de zwaaifase tijdens het lopen: "schop tegen de bal"). Tijdens een 3 weken durende interventie zijn de persoonlijke analogieën geoefend onder wekelijkse supervisie en dagelijks in de thuissituatie. Om de hanteerbaarheid te beoordelen is een vragenlijst afgenomen na de interventie. Potentiële effecten op het lopen zijn onderzocht m.b.v. de 10 Meter Walking Test (10MWT) en de Numeric Rating Scale (NRS).*

Resultaten: *Voor iedere participant was het mogelijk om een analogie voor het lopen te ontwikkelen. Het kwantitatieve gedeelte van de hanteerbaarheids-vragenlijst werd gemiddeld met 69,5% als positief beoordeeld. Na de analogie interventie werd een gemiddelde verbetering van 0.137 m/s (16%) waargenomen op de 10 MWT. Er werd geen verschil in NRS-scores waargenomen.*

Conclusie: *Het ontwikkelen van persoonlijke analogieën is een creatief en uitdagend proces. Deze studie identificeerde verschillende factoren die het proces en ontwikkelen van succesvolle analogieën kunnen beïnvloeden (b.v. de mogelijkheid tot visualiseren en het belang van een betekenisvolle analogie).*

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1. Introduction

Stroke is a major cause of morbidity and mortality worldwide. The overall incidence worldwide ranges from 9 per 100,000 to 20 per 100,000 in some countries (e.g. Finland and Japan; Steiner et al., (2013)). Stroke survivors often need to deal with severe disabilities and may face a long and intensive rehabilitation programme. The most common impairments are a loss of motor functions, speaking ability, and cognitive impairments (Brugge, 2008). The main aim of rehabilitation is to facilitate (physical) recovery in such a manner that patients can return home and participate in the society. In order to do so, patients often need to re-learn important motor skills involved in daily living (e.g., locomotion, object handling, etc.).

One significant part of rehabilitation is regaining motor function e.g. a good mobility and autonomy are a prerequisite for discharge. Traditional learning theories suggest that initial stages of motor (re)learning engage cognitive processes that activate declarative (explicit) knowledge (Fitts & Posner, 1967). For this reason, therapists tend to provide explicit movement instructions outlining the precise steps underpinning skilled movement production. However, for stroke survivors, these explicit instructions may be hard to understand due to cognitive deficits that may affect memory, attention and information processing (Hochstenbach, Mulder, van Limbeek, Donders, & Schoonderwaldt, 1998; Tatemichi et al., 1994). The aim of the current research is to examine the possibility of applying an alternative framework - implicit learning - to the post-stroke rehabilitation environment.

Implicit learning is a form of learning in which skills are acquired without the learner becoming aware of the knowledge that underlies performance of the skill (Berry & Dienes, 1993). It has been argued that implicit, non-conscious processes predate explicit, conscious processes and from an evolutionary perspective. Therefore be more robust to disorders (e.g. psychological and neurological pathologies) that disrupt explicit learning, or memory (Reber, 1992). Masters (1992) pioneered the application of implicit learning to motor skills (implicit motor learning). Implicit

motor learning strategies are hypothesised to circumvent the information processing of declarative (explicit) knowledge relating to the motor skill and limit the involvement of working memory. In this way, implicit learners can become more proficient at a motor skill but are unable to describe the underlying facts and rules about movement production (Masters & Maxwell, 2008). In the sporting domain (where most of this research has been carried out) it has been demonstrated that implicit motor learning is more robust to psychological stress and physiological fatigue. As there is less opportunity for the provocation of the conscious, explicit, rule-based knowledge of the movements, that can disrupt skilled performance (a phenomenon described as „reinvestment" – see Masters & Maxwell, 2008; Masters & Poolton, 2012).

Implicit learning has mainly been explored in sport populations but it may also be advantageous for stroke survivors who need to (re)learn motor skills e.g. walking. The reduced emphasis on working memory and attentional processes of this technique may overcome some of the limitations of traditional, explicit instructions. Explicit motor learning can be impaired in stroke patients, but the ability for implicit learning might be less affected. Support for this assertion comes from neuroscience research examining brain lesions. For example, a lesion in the medial side of the temporal lobe has been shown to affect explicit learning processes, but not implicit ones (Boyd & Winstein, 2003; Vidoni & Boyd, 2007). Unlike explicit memory, it appears almost impossible to completely disrupt implicit memory due to its support by the cerebellum, basal ganglia and the sensorimotor cortex (Boyd & Winstein, 2003).

A number of implicit motor learning strategies have been developed to minimize working memory involvement and the accrual of explicit rules, including dual task learning, errorless learning, withholding / manipulating feedback, and analogy learning (see Masters & Poolton, 2012 for a recent review). Analogy learning is the use of a metaphor or one general analogical rule to integrate the complex rule structure of the to-be-learned skill into a simple biomechanical metaphor that can be

easily reproduced by the learner (Liao & Masters, 2001). It repackages only task relevant bits of information and integrates this into a meaningful memory representation (Liao & Masters, 2001; Masters & Maxwell, 2004). The analogy, therefore, needs to; (a) be known to the learner, (b) address the specific motor problem, and, (c) be less demanding on attention and working memory resources. For example, Lam, Maxwell and Masters (2009b) used the analogy of "reaching your hand into a cookie jar" to describe the appropriate finishing position of the hand following the wrist snap that backspin on a basketball during the performance of a free-throw. Analogy learning may be a promising strategy for the rehabilitation of stroke survivors as it reduces the amount of technical information (explicit rules) processed by the working memory system during motor learning (Lam et al., 2009b). Therefore in the rehabilitation of stroke survivors, using analogies may facilitate motor skills, such as walking performance, in a less attentional demanding way. However, as little is known about how patients and therapists experience the use of analogies in rehabilitation, an essential preliminary step for implementation in every day practice is to explore how analogies might be developed and used within the therapeutic setting.

The main aim of this study is 1) to explore the feasibility and utility of developing personalized analogies to improve walking performance during a three-week analogy intervention period in long term stroke survivors and 2) to explore potential benefits to walking performance using the 10 Meter Walking Test (10 MWT) and the Numeric Rating Scale (NRS). Due to the exploratory nature of this research a case series is adopted.

2. Method

The feasibility and potential effects on performance were examined by multiple single cases, using a single-subject multiple baseline design. All participants received the analogy learning intervention, however each individual received their personalised analogies at different points in time. The variables were observed over time to explore changes in performance before and after introduction of the analogy intervention. An overview of the study design is given in figure 1 below.

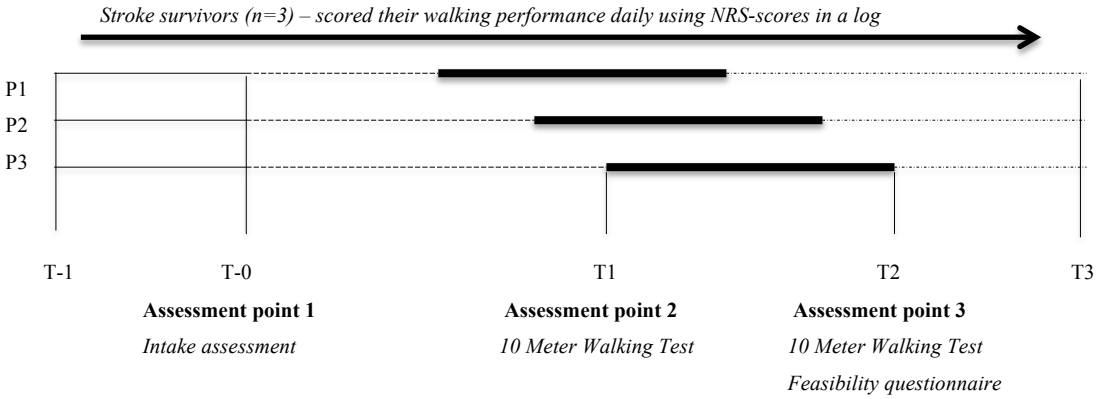

Fig 1. An overview of the study design

Legend:

T-1 = Start: recruiting participants

T0 = Intake assessments + start log book (NRS-scores, see appendix 6)

T1 = Start 3 week analogy intervention

T2 = Stop 3 week analogy intervention

T3 = End study

Selection phase

Baseline phase

Analogy phase

Retention phase

P1 = participant 1

P2 = participant 2

P3 = participant 3

It is hypothesised that if the analogy is successful, the immediate performance improvements should be noted after introducing the analogy. In this way the effect of the analogy learning intervention can be compared across the case series (even though different activities and analogies were used).

2.1 Ethics

This study was approved by the ethical committee of the University of Exeter. Patients who were potential participants were informed via a participant information letter (see appendix 1). Written informed consent was obtained from all participants and a separate audio-visual consent form was signed (see appendix 2 and 3).

2.2 Population

This study included 3 male participants from a non-profit exercise group called AAS "Action After Stroke", at the University of Exeter. Participants were included if they were in their chronic phase of recovery (at least > 6 months after stroke), joined the group sessions every week and experienced problems with motor skills during Activities in Daily Life (ADL). Chronic stroke patients were recruited to control for natural recovery in the acute- and sub- acute phase of stroke rehabilitation. Participants were excluded if they had serious disorders of the locomotor (musculoskeletal) system that could influence the execution of motor functions (e.g. severe rheumatic disorders), or if they were receiving other health care treatments (e.g. physiotherapy or medical treatments) that could influence the findings of the study.

All participants completed an intake form (see appendix 4) during an intake assessment. To describe the participant characteristics, the MMSE (Mini-mental State Examination), MSRS (Movement Specific Reinvestment Scale) and RMI (Rivermead Mobility Index) were used (Table 1).

Table 1. Description measurements intake

Measurement	**Goal**	**Score**	**Interpretation**
MMSE	To determine the cognitive level of the participants (Folstein, Folstein, & McHugh, 1975)	Score 0-30	A low score on the MMSE, correlates with a low cognitive level
MSRS	To determine the propensity of the participants to reinvest in explicit knowledge supporting movement execution (Masters	Score 10-60	High scores on the MSRS correspond with a higher propensity for reinvestment.
RMI	To determine the mobility disability	Score 0-15	A high score on the RMI indicates better mobility

2.3 Procedure

The total study period was 8 weeks and consisted of three phases 1. Baseline, 2. Analogy learning intervention and 3. Retention phase (see figure 2 below).

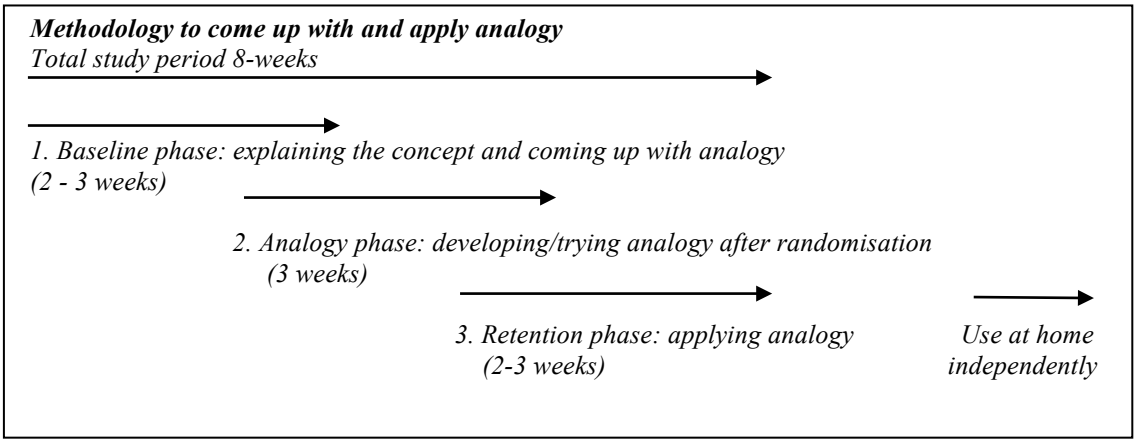

Fig. 2. *Overview of creating and applying analogies*

1. Baseline phase

All participants started with an intake assessment to define their goals and to collect their baseline characteristics. The participants started by completing their log books, in which they daily scored their walking performance on a NRS (Numeric Rating Scale). During this phase the researchers analysed the participants' activities and started the process of creating the analogies. The baseline phase took 2 to 3 weeks and at the end of the baseline phase each participant completed a 10 Meter Walking Test (MWT)(Collen, Wade, & Bradshaw, 1990).

2. Analogy phase

Analogy learning was explained to the participants: what it is, how it will be used and what it can do. They received a few example analogies based on their activities developed by the researchers. Together the researcher and participant tried to reach consensus about what the most successful analogy could be. Participants applied the analogies in practice and made amendments (if necessary) until they had a final analogy to use. The total period of the analogy learning intervention was 3 weeks. At

the end of this phase, a specially designed feasibility questionnaire was completed and a further 10 MWT completed.

3. Retention phase

The therapist reduced the frequency and extent of support once the participants were familiar with using analogies. The participants were now encouraged to use the knowledge they have been taught and apply the principles of analogy learning to other tasks in daily life.

2.4 Measurements

Feasibility was explored via a feasibility questionnaire and potential improvements on walking performances were assessed by objective and subjective measurements.

2.4.1 Feasibility

To determine the feasibility of analogy learning a questionnaire was developed (see appendix 5). The questionnaire had 15 closed and 6 open questions relating to: experience of the analogy learning intervention, the physical and emotional demands of the intervention and the organisation of the treatment. The aim of the questionnaire was to determine whether the participants could effectively use the analogy and if it was something they could involve in their daily activities.

2.4.2 Performance

Performance was measured by both subjective and objective measures.

Subjective measure

NRS (Numeric Rating Scale)

To assess potential improvements on performance the participants were asked to score their walking performance every day using the NRS-scale. The NRS is an 10-point Likert scale that assesses the performance of the self-selected activity ranging from 10 ('excellent') to 1 ('poor') (Williamson & Hoggart, 2005). They reported their scores in a daily log book (see appendix 6).

Objective measures

The 10 Meter Walking Test (10 MWT) was used to assess potential functional performance improvements (Collen et al., 1990). The 10 MWT is a physical performance test that evaluates the walking speed in meters per second over a 10-meter distance. The test was developed for elderly and patients with neurological diseases. The 10 MWT was performed, before and after the analogy intervention.

2.5 Data analysis

This study used quantitative and qualitative methods to determine the feasibility and potential performance effects of analogy learning. To make sure that all participants are sufficient and competent with the concept of analogy learning, only the data of the participants who scored a compliance of > 75% over 8 weeks will be analysed. Compliance will be assessed via the completion of their log books.

Feasibility questionnaire:

The outcome of the quantitative part (15 closed questions) of the feasibility questionnaire were scored as positive (+) or negative (-) related answers. The ordinal variables were scored as positive if the answer lies within the two highest weighted answers of the four possibilities. Dichotomous variables, "yes" or "no" are scored as + or -.

Additional comments and open questions were used to describe personal experiences of the participants and good examples are quoted.

Performance:

10 MWT /NRS

The difference in 10MWT performance before and after the analogy intervention was compared to both the SRD (Smallest Real Difference) of 0.05 m/s and the MCID (Minimally Clinically Importance Difference) of 0.16 m/s (Perera, Mody, Woodman, & Studenski). When a significant change in NRS-scores is identified, these data will be presented in a line graph.

3. Results

In this study the compliance was >75% for all participants (87,5%, 98,2% and 100%, see appendix 7).

3.1 Participants characteristics

This study included three male participants with a right-sided infarct, 6, 1 and 3 years post-stroke. Each presented with a walking deficit that they wanted to improve. Participant 1 wanted to work on his walking gait in a less conscious way. During his walking he complained about constantly thinking about lifting and placing his foot. Participant 2 wanted to be more confident and more fluent in his walking. Participant 3 is not independent in daily life and needs supervision for his activities. He complained about a low level of self-confidence during walking. He wanted to walk less consciously.

Table 2. Participants, characteristics

Participant	**1**	**2**	**3**	**Mean**	**SD**
Side infarct (Left/Right)	Right	Right	Right		
Sex (Male/Female)	Male	Male	Male		
Age	76	87	70	77,67	8,63
Use of walking aids (No/Yes)	No	Yes	Yes		
Post-stroke (years after stroke)	6	1	3	3.33	2.52
Mini-Mental State Examination (Score)	28	30	28	28,67	1,15
Movement Specific Reinvestment Scale (score)	35	38	43	38,67	4,04
Rivermead Mobility Index (score)	12	12	4	9,33	4,67

3.2 Feasibility: Open Questions

Based on the questionnaire all participants agreed that there was enough supervision during the training and it was clear how to use the analogies. For all participants, we were able to come up with a personalized analogy (see table 3), and they all agreed that their analogy was meaningful for them. They all reported that they had some improvements in walking and they would recommend analogy training to others. The way the participants experienced the analogy training, however, differed (see appendix 8).

Table 3 Overview goals and analogies

Participant	**Analogy**	**Goal**
1	*"Imagine like you are stepping over a rowing machine"*	Improving lifting and placing his foot Walking in a less conscious manner
	"Imagine like you are walking over a frozen lake and you don't want the ice to break"	
2	*"Imagine like you are following the footprints in the snow"*	Creating a step- through gait, walking more fluently Walking without constantly thinking
3	*"Imagine like kicking the football in front of you"*	Increase his confidence in walking Walking with less effort, more fluently Walking in a less conscious manner

Participants' experiences with analogy intervention

Participant 1 reported that the analogy training was useful, and he liked a different way of learning.

"*Very useful, but I would prefer the training in the beginning of the rehabilitation, it is difficult to change behavior after such a long time"*

All participants' pointed out that they liked a different way of learning.

" It was good to learn a different way of learning. A new way to improve things."
"It was very helpful to think in a different way about the movements"

Participants' experiences with visualising the analogies

The ability to visualise the analogy differed per participant. For participant 2 it was no problem to visualise, however, the other participants struggled with this skill, as it required a lot of thinking for them. Those two participants also reported that the more they practiced the easier it became to use the analogies. Participant 1 reported that the *"frozen lake"* analogy over the *"rowing machine"* analogy was easier to visualise.

Participant 1:

"In the beginning it's difficult. After practice it was better."
"I needed to think a lot."

Participant 3 mentioned that his analogy was based on kicking the ball with his left leg, while in the past he played football with his right leg, which made it difficult for him.

"It's difficult to go against my intuition, if the analogy was for my other leg it would be easier to visualise"

For an overview of all the outcomes of the open questions of the feasibility questionnaire see appendix 8.

3.3 Feasibility: Closed Questions

The participants overall scored positively on the questionnaire (mean: 7.67 points; 69.5% SD: 3,06 points; 27,8%). The scores per participant are shown in table 4. For an overview of all the closed questions see appendix 9.

Table 4 Outcome closed questions

Question nr.		**Max score**	**Part 1**	**Part 2**	**Part 3**
1. General	Experience?	+	+	+	-
2. General	Numeric score training (1-10)				
3. Physical load	Physically tough?	+	-	+	+
4. Physical load	Fatigued after training?	+	+	+	-
5. Physical load	Intervention intensive?	+	-	+	-
6. Mental load	Need to think hard?	+	-	+	-
7. Mental load	Clear how to use the analogy?	+	+	+	+
8. Emotional load	Meaningful analogy?	+	+	+	+
9. Emotional load	Emotional experience?				
10. Organization	Enough supervision?	+	+	+	+
11. Organization	Satisfied about supervision?	+	+	+	+
12. Using the analogy	Difficult to visualise?	+	-	+	-
13. Using the analogy	Difference in analogies?				
14. Using the analogy	Easier after practice?				
15. Effects	Improvements?	+	+	+	-
16. Effects	Side effects?				
Total Points		11 points	7 points	11 points	5 points
%		100%	63%	100%	45, 5%

Legend:
- = 0
+ = 1
■ = Question left out analysis

Question 2 was left out because we only analysed the ordinal 4-points scales and dichotomous variables. Question 13 was left out because it was not relevant and

applicable for all participants. Question 15 and 16 are left out because we did not classify them as positive or negative.

3.4 Walking performance

No difference was identified in NRS-scores during the intervention (see appendix 7), however, the 10 MWT did improve. Two of the three participants showed a meaningful change in walking speed on the 10MWT with a 15% (change: 0.086 m/s) and 44% (change: 0.32m/s) improvement on 10MWT see figure 3.

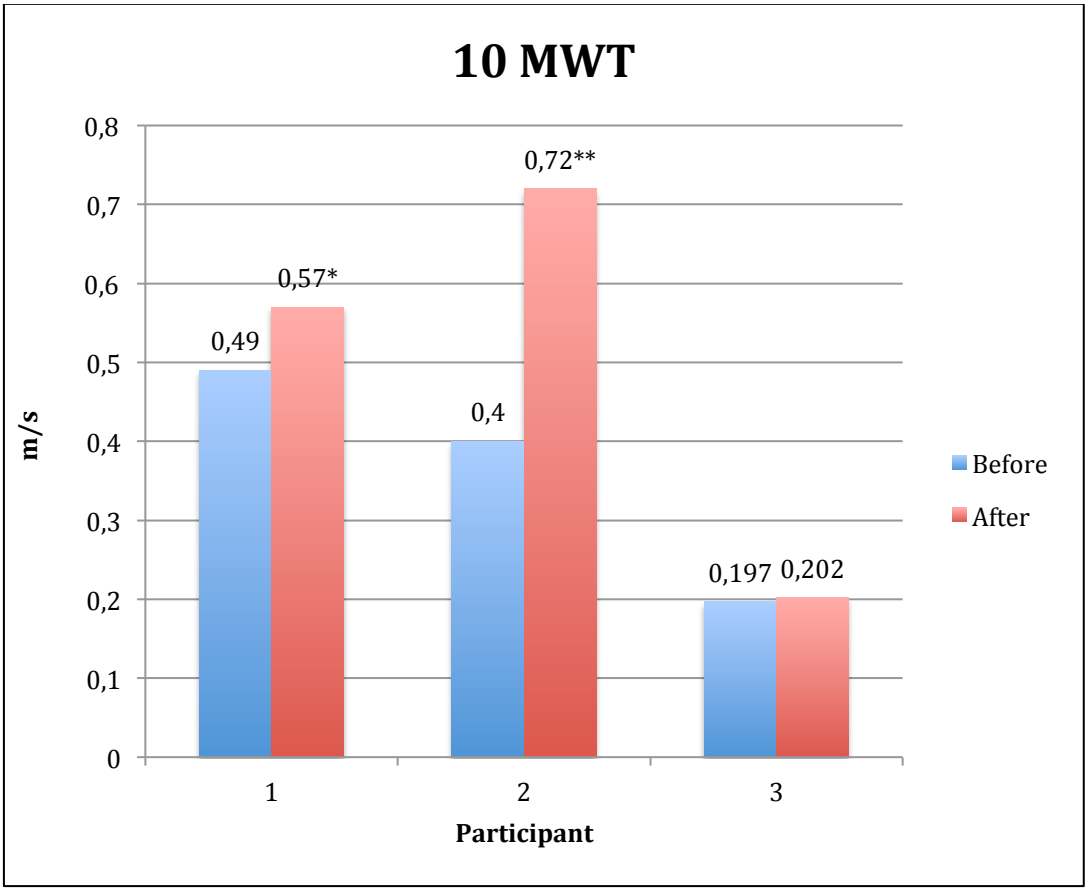

Figure 3 Results 10MWT in m/s before and after the analogy intervention

** SRD obtained > 0.05 m/s*

*** SRD and MCID obtained >0.16 m/s*

4. Discussion

The aim of this study was twofold: 1) to assess the feasibility and utility of developing personalized analogies and 2) to explore the potential benefits of analogy learning. The findings of our study demonstrate that developing personalized analogies to improve walking in long term stroke survivors is a creative and challenging task. Analogy learning seems a feasible learning strategy and might contribute to a better walking performance (speed).

4.1 Feasibility

During this study we were able to create and develop personal analogies for each participant within a 3-week intervention period. It can be a time consuming process to find a suitable analogy because it requires creativity of the therapist. In some cases adjustments were necessary to develop a good suitable analogy, however, if the right analogy is found, immediate improvement should be noted.

The feasibility questionnaire showed that in general the participants where positive about the intervention, the questionnaire identified several factors that may influence the chance of a successful analogy and the process of developing tailored analogies. The most important two were: attentional load and meaningful/biomechanical correct analogies.

First, in this study attentional load seemed to influence the way the participants experienced the analogy intervention. Two factors that may possibly influence the degree of attentional load are: visualisation abilities and attentional focus.

- The ability to visualise analogies seemed to be a factor that affected the way the participants experienced analogy learning in this study. This lead to the hypothesis that individuals who cannot visualise or have difficulties with visualising might not be suitable participants for analogy learning. When experiencing difficulties with visualising, the intervention tends shift to another not intended direction, which is attentional demanding. Therefore the benefits of the implicit form of learning are minimized. In other studies of

analogy learning, visualisation was never discussed and did not seem to play an influential role. Previous studies were mainly performed in the sports domain. Our study, however, included stroke survivors experiencing some degree of cognitive problems, exposing the role of the ability to visualise.

- Another factor that may influence the attentional load in a positive way is attentional focus (internal/external). Analogies may switch attentional focus from an internal focus of attention (directed towards the performers own body movements e.g. how to lift and place the foot) to external focus of attention (focusing on the effects of the body movement) (Wulf, Hoss, & Prinz, 1998). According to the Constrained Action Hypothesis an external focus of attention promotes an automatic mode of movement control, whereas an internal focus may constrain automatic control processes (Wulf, McNevin, & Shea, 2001). Wulf, McNevin and Shea (2001) found that, in line with the Constrained Action Hypothesis, an external focus of attention was associated with decreased attentional demands in contrary to an internal focus of attention that was associated with an increased attentional demand.

Secondly, when developing analogies, the analogy has to be meaningful and relevant for your participant e.g. the analogy should address the biomechanical problem in the performance. Participant 1 came up with his own analogy, as our proposed examples were not recognisable or meaningful to him, what made it hard to visualise. He created his analogy "stepping over a rowing machine" to help him lifting his foot. He thought of this analogy because he tripped over a rowing machine, therefore this analogy was easier to remember. This may explain why one analogy might work better for one person than for the other. This phenomenon refers to "chunking", which is the repackaging of task relevant 'rules' and knowledge into a single, all encompassing biological metaphor (Masters & Maxwell, 2004). It is very important that these "bits" of information are relevant or meaningful for the individual in order to create successful and larger chunks (Chase & Simon, 1973; de Groot, 1965; Gabbett & Masters, 2011). This may support the contention that developing analogies is a process, which a professional does together with the client and that in

order to create successful analogies the professional needs to know the preferences and personal background of the client.
In work of Masters and Liao (2003), Chinese participants used a literal translation of the right-angled triangle analogy, however, when applying the analogy, confusion raised within the participants about how to implement this analogy. Based on this study, Poolton, Masters and Maxwell (2007) redeveloped the "triangle" analogy to a Chinese cultural relevant analogy. Thus although the triangle analogy was relevant and meaningful for native English-speaking participants, its literal translation raised confusion for the Chinese population. Just like in our study, these findings illustrate relevance of meaningful analogies.

4.2 Potential benefits walking

Improvements on walking speed (10MWT) were observed in two of the three participants. Due to an unexpected incident in the second week of the intervention, participant 3 was exposed to additional medication (tramadol) leading to severe drowsiness. This lead to a significant decrease in the execution of his daily activities, including walking. Although initially the analogy seemed successful, we could not measure an improvement as the 10 MWT was repeated after three weeks. In NRS-scores no significant change in scores were identified in any of the participants (see appendix 7).

During the analysis of this study we observed that the subjective (NRS) and objective (10MWT) measures did not correspond with each other. A possible explanation for that may be that the quality of walking depends on many factors, of which self-confidence is an important one. Self-confidence influenced the way participants scored their walking (NRS-scores) in this study. Although the objective measures improved, one participant explained that his perceived NRS-scores also depended on the way he felt, his level of self-confidence didn't change and therefore he did not experienced improvements in walking (NRS-scores).

4.3 Methodological quality of the study

Some methodological aspects of our study needs to be addressed. Strong aspects of this study were the design and the fact that this is the first study that evaluated the process of developing and creating personalized analogies in a rehabilitation setting.

By using single case studies, we wanted to gain rich data by going in-depth with a limited amount of participants. In this way we tried to provide anecdotal evidence, a more detailed description of the participants experiences and come up with hypothesis and indications for future research.

Most studies of analogy learning were performed in the sports domain (Lam, Maxwell, & Masters, 2009a; Lam et al., 2009b; Liao & Masters, 2001). Other studies, however, demonstrated that implicit motor learning might be beneficial in a rehabilitation setting (for review see Steenbergen et al (2010)). Orrell et al (2006) showed that participants with stroke benefited from using errorless (implicit) learning. They concluded that the application of implicit motor learning techniques in rehabilitation setting might be beneficial. Our study may support the appeal for implicit motor learning in rehabilitation and may contribute to the fact that implicit motor learning is applicable in rehabilitation.

Contrary to other studies in athletes where analogies have been explored, we wanted to know whether it would be possible to create personal analogies for the same problem (walking). For instance in the studies by Lam et al (2009b) and Liao & Masters (2001) one single analogy e.g. in basketball the “cookie char” analogy or in table tennis the “triangle” analogy was used. In contrast to these studies, our study was based on the process of developing and creating analogies.

A few limitations of this study should be acknowledged. Firstly our study had a small sample size. Although initially we strived to recruit 6 till 8 participants we finally included 3 participants for our study. We were working with long-term stroke survivors, therefore it was difficult to recruit participant who still wanted improve their motor skills. This small sample size makes it hard to generalise our findings to the greater population.

When reviewing the feasibility questionnaires we found out that participant 1 interpreted the questions related to physical load differently. In the additional comments he explained his score by saying that he needed to think hard (see appendix 9). This refers more to the cognitive load then a physical load. A right interpretation of the questions might have led to an even more positive outcome.

4.4 Implications for future research

Based on the findings of our study, several aspects could be addressed in future studies:

1. Phase of recovery.

From our results it seems that the phase of rehabilitation in which the patient is, may influence the feasibility of the analogy approach. Similar to sport experts who developed their own technique through many years of experience, it is hard for long-term stroke survivors to change their technique after several years of rehabilitation. In future research it would therefore be interesting to explore analogy learning in the acute or sub-acute phase of rehabilitation by using another research design e.g. controlled experimental designs to control for the bias of natural recovery.

2. Optimal measures and measuring time point

We hypothesised that performance improvements would be noted with the daily NRS measurement, directly after introducing the analogy. In this study the NRS did not change after the intervention, in contrast to the results of the 10 MWT, which was performed after 3 weeks. Therefore it might be better to use objective measures

such as the 10MWT, straight after the first session of analogy learning to detect immediate effect on walking performance after the intervention.

3. Establish suitability of participants
It might be worth to consider selecting participants based on their ability to visualise. This in order to let analogy learning to be a less attentional demanding intervention what is what you would like to strive for as it is one of the characteristics of implicit motor learning.

4.5 Conclusion

To apply analogy learning in an appropriate and efficient way in the rehabilitation setting, further research seems necessary. It would be interesting to explore analogy learning in the acute- or sub- acute phase of rehabilitation. Furthermore it would be appealing to examine objective measures straight after introducing the analogy. To establish the suitability of the participants, it might be worth to consider selecting participants on their visualising abilities.

In this study we were able to develop and create personalized analogies for each participant. The process of creating successful analogies requires creativity and close involvement of the therapist what can be challenging process. Overall the participants in this study experienced the analogy learning intervention positively and a meaningful improvement on walking speed was established for two of the three participants. This study also highlights the importance of the side effects of medication affecting motor function. Based on this pilot study we conclude that analogy learning may be a feasible and applicable intervention, although these findings should be confirmed by larger studies.

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Appendix 1 Patient information letter

SPORT AND HEALTH SCIENCES

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Telephone +44 (0)1392 7222891
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(Patient) Information Letter
Analogy learning: *Different explanation, less frustration?*

Dear Sir/Madam,
You are asked to participate in a study that seeks to examine whether a certain form of therapy: *analogy learning* is feasible and beneficial for post-stroke patients. Re-learning motor skills can be frustrating due to the amount of step-by-step procedures that need to be remembered. Analogy learning uses metaphors about how to reproduce a certain movement which may mean less frustration and better performance.

This study will start by collecting background information about you (e.g., physical activity level, training goals, difficulties in activities in daily life etc.) From this information we hope to tailor treatment based on your individual needs (e.g. therapy based on walking, balance or transfers).

The intervention will consist of three phases and last for ten weeks:
- receiving usual care (measurements related to movement performance)
- receiving analogy learning
- receiving usual care (repeating measurements + questionnaire)

The burden, risks and benefits associated with participation

Burden: If you are participating in this study you are expected to be present for your typical training at the Action After Stroke group twice a week over the ten weeks. You will attend for three testing sessions (lasting about 30-45minutes) where your performance in tasks will be videotaped during this time. You will keep a daily log book whereby you assess one aspect of your mobility.

Risks: This study was approved by the ethical commission of the University of Exeter. The study will as be under supervision of Zuyd University of Applied Sciences and the University of Exeter.

Benefits: The goal of this intervention is to improve your motor skill and activity level. By creating goals and applying analogy learning this study offers you a way to improve motor skills based on your needs.

Voluntary participation
Participation of this study is on a voluntary basis and you can decide to drop out at any time without consequences.

Confidential use of data
All the data we collect will be stored on a password protected computer or in a locked filing cabinet. No one will be told your individual results. We may write the study up as a paper and present the group results to other researchers but your information will remain confidential. Only the people who are doing the tests will be able to see this individual information.

What if I have a question?
If you have any questions regarding the study please contact Dr Mark Wilson (01392-722891; mark.wilson@ex.ac.uk) or Ms Li-Juan Jie (0901431jie@zuyd.nl) or Ms Floor te Lintel Hekkert (0906409lintelhekkert@zuyd.nl).

Appendix 2 Informed consent

SPORT AND HEALTH SCIENCES

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Analogy learning
Different explanation, less frustration
(University of Exeter/Action After Stroke Group/ Zuyd University)

Dear Sir/Madam,
Thank you for agreeing to participate in our research. If you agree with the following points, we would like to ask you to sign this form.

1. I have read the Information sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.
2. I will be asked to take part in an analogy learning training study that involves me being video-taped
3. I will be required to keep a daily log where I rate my performance in the skill I am training over ten weeks
4. My participation in this project is entirely voluntary
5. I am free to withdraw from the project at any time without disadvantage
6. The raw data on which the results of the project depend will be retained in secure storage
7. The results of the project may be published but my anonymity will be preserved.
8. I wish to be informed about the results of this study when they will be published? Yes/No

Name:

Date of Birth:

Date:

Signature:

Signed responsible researcher, clarifies that the person above has been provided with both written and verbal information and that questions were answered as well as possible.
Name:

Function:

Date:

Signature:

This study has been approved by the division of Sport and Health Sciences' Ethics Committee

Appendix 3 Audio Visual Statement

Production Title: **Different explanation, less frustration**

(Zuyd University/University of Exeter/AAS)

Signed:
Name: .....
Adress: .....
Postal code : .....Place: .....
Date of birth: ..... Place of birth: .....

Declares hereby:
1. To give permission to manufacture audio-visual material of him/her during the therapy session

2. That he/she is completely informed through the responsible researcher what the main goal is for the audio-visual material and how it will be used.

3. That there is no objection against using the material(or parts of it) with the following institutes or target groups.
□ Zuyd university of applied science.
□ University of Exeter

4. That there will be no payment for manufacturing or using the material through the producer of the material.

5. That all rights are reserved to the producer of the production.

Place: **Signature:**

Date:

Responsible staff member:

Name: **Signature:**

Function:

A copy of this document will be kept at any time with the participant who gives permission for the audio visual material.

Appendix 4 Intake form

Thank you for joining our study, we really appreciate your participation. We would like you to complete this intake form. All personal information will be used confidentially and will only be accessible for a few researchers of this project. When using this information it will always be anonymous.

Instructions:

If there is closed question like **Yes/No** or **Left/Right** please encircle the correct answer. When there is **If Yes, which** or **If Yes, where**, please explain. Could you please write down the answers clearly and readable. *If there are any questions, do not hesitate to ask us for help.*

GENERAL INFORMATION	
1. Surname:	
2. First name:	
3. Date of birth: (Day/month/year)	_____/_____/____.
4. Sex:	Male/Female
5. E-mail address:	
HEALTH RELATED	
6. Side of brain-damage due to the stroke:	Left/Right
7. Date of stroke: (Year/Month)	_____/_____.
8. Do you have other complaints or diseases?	Yes/No If yes, which:
9. Do you use medication?	Yes/No If yes, which:

DISABILITIES	
10. Do you use a wheelchair:	Yes/No
11. Do you use walking aids**:**	Yes/No If yes, which:
12. Do you use any other aids?	Yes/No If yes, which:
PYSIOTHERAPY	
13. Do or did you have physiotherapy for your stroke rehabilitation?	Yes/No If yes: What is/was the duration? _____months What is/was the intensity (e.g. 30min 2 times/week)? _____min _____times/week
14. Do you participate in any other health related treatments?	Yes/No If Yes, which:
15. Is there a particular activity that you would like to improve?	Yes/No If Yes, which:
16. Do you have any expectations of the trainings?	Yes/No If yes, what kind of expectations? (e.g. positive/negative)
ACTIVITY	
17. Do you experience difficulties with Activities in Daily Life (ADL) e.g. walking, balance, transfers, sitting or rising from a chair, opening a jar?	Yes/No If Yes, which:
18. What are your interests	

and main activities?	
19. Did/do you have a favourite sport?	Yes/No If Yes, which:
20. What (past) profession (work) did/do you practice?	
PARTICIPATION	
21. Do you experience limitations due to the consequences of the stroke?	Yes/No If Yes, which:
22. Do/did you experience changes or difficulties in tasks e.g. cleaning, gardening, grandparent?	Yes/No If Yes, which:
BODY FUNCTION/STRUCTURE	
23. Do you experience pain?	Yes/No If yes, where:
24. Do you experience physical deficits?	Yes/No If yes, how:
25. Do you experience balance or co-ordination problems?	Yes/No If yes, how:
26. Do you experience cognitive deficits?	Yes/No If yes, how:
27. Do you experience language problems?	Yes/No If yes, how:
28. Do you experience a loss of dexterity?	Yes/No If yes, where (e.g. arm, hand function):
29. Do you experience any emotional problems?	Yes/No If yes, how:

Thank you for your co-operation

Appendix 5 Feasibility questionnaire

Questionnaire Analogy learning		
Name:		
Your training goal (activity):		
Your analogies:		
GENERAL QUESTIONNES	**Answer**	**Additional comments**
1. Did you like the trainings?	Yes/No	
2. How did you experience the analogy training? Please give a score	0 – 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10 (Bad) (Excellent)	
PHYSICAL LOAD	**Answer**	**Additional comments**
3. Was the training physically tough?	○ Very tough ○ Tough ○ A little tough ○ Not tough at all	
4. How fatigued were you after using the analogy training?	○ Very fatigued ○ fatigue ○ A little fatigued ○ Not fatigued at all	
5. Do you think the analogy training was intensive?	Yes/No	
MENTAL LOAD (memory/cognition)	**Answer**	**Additional comments**
6. Did you need to think very hard when using the analogy?	○ Very hard ○ Hard ○ A little hard ○ Not hard at all	
7. Was it clear to you, how to use the analogy?	Yes/No	
EMOTIONAL LOAD	**Answer**	**Additional comments**
8. Was the analogy meaningful for you?	○ Very meaningful ○ Meaningful ○ A little meaningful ○ Not meaningful at all	
9. How did you experience the training? (e.g. anxious, insecure, satisfied, delighted, fun)		

ORGANISATION	Answer	Additional comments
10. Was there enough supervision during the training?	Yes/No	
11. Were you satisfied about the supervision?	○ Very satisfied ○ Satisfied ○ A little satisfied ○ Not satisfied at all	
Using the Analogy	**Answer**	**Additional comments**
12. Was it difficult to visualise the analogy?	Yes/No	
13. If you had more than one analogy: Could you visualize one analogy better than the other one?	Yes/No If yes, why:	
14. Was it easier to use the analogy the more you practice?	Yes/No	

Effects	Answer	Additional comments
15. Did the intervention bring any improvements as regards to your goal(s)?	○ Very much improvements ○ Some improvements ○ Little improvements ○ No improvements at all	
16. Did the training bring any side effects?	Yes/No	Which?
17. What elements did you like about the analogy trainings?		
18. What elements did you not like about the analogy training?		
19. Do you have any recommendations for improvements?		
20. Would you recommend analogy training to others?		
21. Do you have any other comments?		

Appendix 6 Log book

Daily log before analogy intervention

Monday, ___-___-201_

How did your activity go?

Evaluation of activity		
Activity	How long did you practice?	Score yourself on today's performance 1: poor →10: excellent
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10

Comments:

Tuesday, ___-___-201_

How did your activity go?

Evaluation of activity		
Activity	How long did you practice?	Score yourself on today's performance 1: poor →10: excellent
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10
		1 2 3 4 5 6 7 8 9 10

Comments:

Daily log after analogy intervention

Monday, ___-___-201_

How did your activity go?

Evaluation of the activity and the use of analogy			
Activity	*Did you use the analogy?*	*How long did you practice?*	*How did it go?* 1: poor →10: excellent
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10

Comments:

Tuesday, ___-___-201_

How did your activity go?

Evaluation of the activity and the use of analogy			
Activity	*Did you use the analogy?*	*How long did you practice?*	*How did it go?* 1: poor →10: excellent
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10
	Yes/no		1 2 3 4 5 6 7 8 9 10

Comments:

Appendix 7 Result NRS-scores

Participant	Response rate (compliance)	Baseline	Analogy intervention	Retention	Overall Mean NRS-score
1	87.5%	Mean: 5.25 SD: 1.14	Mean: 5.17 SD: 1.20	Mean: 5.00 SD: 1.41	5.24
2	98.2%	Mean: 3.60 SD: 0.5	Mean: 4.00 SD: 0	Mean: 5.00 SD: 0	4.22
3	100%	Mean: 4.48 SD: 1.75	Mean: 4.08 SD: 3.89	Mean: 4.33 SD: 0.86	4.36

Appendix 8 Results Open Questions

Question	PT	Comments	+/-
9. How did you experience the analogy training?	1	*"Very useful, but I would prefer the training in the beginning of the rehabilitation, it is difficult to change behavior after such a long time" "It's difficult to change my mind, difficult to change fixed ideas."*	+
	2	*"Helpful and delighted. Nice to learn something different."*	+
	3	"*It is difficult to go against my intuition; if the analogy was for my other leg it would be easier to visualise."*	-
17/18. What elements did you (not) like about the training?	1	*"I liked the working on my walking, but I would prefer it in the beginning after my stroke and not after such a long time."* *"Visualizing was very difficult. But no particular things that I disliked."*	+/- +/-
	2	*"It was really helpful to think in a different way about the" movements.*	+
	3	*"I was a right sided football player, no I needed to kick the ball with my left leg, that was my wrong leg."*	-
19. Do you have any recommend-dations for improvements?	1	*"Very useful but in other time of the rehabilitation because it is difficult to change behavior you had since the stroke, if you learn it in the beginning it would be easier."*	+/-
	2	*"Do it a lot, I need to use it more, I still use my own method."*	+
	3	*"No"*	
20. Would you recommend analogy training to others?	1	*"Yes it definitely can be useful."*	+
	2	*"Yes, it is a good thing to learn something In a different way and to see that you can improve."*	+
	3	*"Yes it offers alternative ways of learning"*	+
21. Do you have any other comments?	1	*"It was good to learn a different way of learning. A new way to improve things."*	+
	2	*"Useful, it changed my way of thinking while I was moving. Now I don't think about the specific steps but I think about the analogy."*	+
	3	*"No"*	

Appendix 9 Results Closed Questions

Question	PT	Answer	Additional comments
1. Did you like the training?	1	Yes	
	2	Yes	
	3	No	*"it goes against my instinct kicking with my right foot."*
2. How did you experience the analogy training? Please give a score	1	3	*"Difficult to change my attitude of my usual pattern . I would like to have it in the beginning after the stroke."*
	2	6	
	3	3	
3. Was the training physically tough?	1	Tough	*"I needed to think a lot."*
	2	Not at all	
	3	A little	
4. How fatigued were you after using the analogy training?	1	A little	
	2	Not at all	
	3	Fatigued	
5. Do you think the analogy training was intensive?	1	Yes	*"Yes a lot of thinking"*
	2	No	
	3	Yes	
6. Did you need to think very hard when using the analogy?	1	Very hard	
	2	Not at all	
	3	Hard	
7. Was it clear to you, how to use the analogy?	1	Yes	*"In beginning difficult after practice it was better."*
	2	Yes	
	3	Yes	
8. Was the analogy meaningful for you?	1	Meaningful	*"frozen lake was more meaningful than the rowing machine. The lake was easier to visualize because it was bigger"*
	2	Very meaningful	
	3	Meaningful	
10. Was there enough supervision during the training?	1	Yes	
	2	Yes	
	3	Yes	
11. Were you satisfied about the supervision?	1	Satisfied	
	2	Very satisfied	
	3	Very satisfied	
12. Was it difficult to visualise	1	Yes	*"Difficult to change mind, difficult to change fixed ideas."*

the analogy?	2	No	
	3	Yes	*"because of the affected leg"*
13. If you had more than one analogy: Could you visualize one analogy better than the other one?	1	Yes	
	2	-	
	3	-	
14. Was it easier to use the analogy the more you practice?	1	Yes	
	2	No	
	3	Yes	*"It helped the concentration during the walking, it stopped distracting me from thinking about my movements, and it got me in a rhythm."*
15. Did the intervention bring any improvements as regards to your goal(s)?	1	Some	*"placing of the foot + balance"*
	2	Some	*"it improved walking speed"*
	3	Little	
16. Did the training bring any side effects?	1	No	
	2	No	
	3	No	