A Different Point of View: The Evaluation of Motor Imagery Perspectives in Patients With Sensorimotor Impairments in A Longitudinal Study

Szabina Gäumann
Reha Rheinfelden https://orcid.org/0000-0002-1535-2063
Rahel Sarah Gerber
Zurcher Hochschule fur Angewandte Wissenschaften
Zorica Suica
Reha Rheinfelden
Corina Schuster-Amft (c.schuster@reha-rhf.ch)
https://orcid.org/0000-0003-1120-4423

Research article

Keywords: Motor imagery, motor imagery perspective, neurorehabilitation, sensorimotor impairment

Posted Date: July 24th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-44794/v1

Version of Record: A version of this preprint was published at BMC Neurology on July 27th, 2021. See the published version at https://doi.org/10.1186/s12883-021-02266-w.

Abstract

Background

Motor imagery (MI) has been successfully applied in neurological rehabilitation. Little is known about the spontaneous selection of the MI perspectives in patients with sensorimotor impairments. What MI perspective is selected: internal (first- person view), or external (third-person view)? The aim was to evaluate the MI perspective preference in patients after stroke (STR), with Multiple Sclerosis (MS) or Parkinson's disease (PD).

Methods

In a longitudinal study including four measurement sessions over two weeks, MI ability and MI perspective preference in both visual and kinaesthetic imagery modalities were assessed using the Kinaesthetic and Visual Imagery Questionnaire including 20 items (KVIQ-20), mental rotation, and mental chronometry. Additionally, patients' activity level was assessed. Descriptive statistical analyses were performed regarding different age- (≤44, 45-63, 64≤) and activity levels (inactive, partially active, active), and KVIQ-20 movement classifications (axial, proximal, distal, upper and lower limb).

Results

In total, 55 in- and outpatients (25 SRT, 25 MS, 5 PD; 25 females; mean age 58±14 years) were included. At the first measurement session, the mean mental rotation score was 27±4.1 out of 32. For mental chronometry, a congruency ratio of 1.0±0.3 was determined. The KVIQ-20 scores for the visual and kinaesthetic subscales were 62.4±16.2 and 58.2±17.2. The internal MI perspective was favoured in 66.5% on the visual subscale and in 72.7% on the kinaesthetic subscale. The external perspective was preferred in 30.3% on the visual subscale and in 26.5% on the kinaesthetic subscale. Over the four measurement sessions, patients became more consistent in their MI perspective selection. MI perspective changes occurred mainly during imagination of shoulder, arm and neck movements. During imagination of foot and finger movements their MI perspective was more constant. Results showed a tendency to use an external perspective in patients older than 64 years and in patients with a descreasing physical activity level. Axial and proximal movements were commonly imagined using the external perspective.

Conclusion

It is recommended to evaluate the spontaneous MI perspective selection to design patient-specific MI training interventions. Distal movements (foot, finger) may be an indicator when evaluating the consistency of the MI perspective in patients with sensorimotor impairments.

Trial registration

This is a research project involving persons other than a clinical trial according to the Human Research Act other than clinical (non-clinical trial). Registered: EKNZ 2015-172, 19. Mai 2015

Background

The active imagination of movements also called motor imagery (MI) is defined as the mental representation of an action without engaging in its actual execution (1).

In sport psychology, studies frequently reported that MI has a positive effect on motor performance (2, 3). Over the last decades, MI has been successfully introduced to a wide range of disciplines, e.g.in education, medicine, and music (4). In addition, the MI technique has been successfully integrated in rehabilitation because it facilitates positive neurophysiological changes in the central nervous system and therefore, brain plasticity (5, 6). Neuroimaging studies using positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) demonstrated that physical execution and mental rehearsal of a movement show similar brain activation pattern (7, 8). In neurological rehabilitation, MI seems to be an effective complementary therapy for patients with sensorimotor impairments providing additional benefits if added to conventional therapies (9–11). Patients seem to advantage from MI because it can be safely practiced alone, thus expanding the time spent with rehabilitation-related activities (12).

There are two different perspectives described to imagine a movement: a) an internal and b) an external perspective. The internal view describes the first-person view, where the imaginer visualises the movement through his or her own view, comparable to what you would see through a camera mounted on the head. The external perspective describes the third-person view, where the imaginer watches him or herself performing an action from a spectator's position (13, 14).

So far, preference was given to the internal perspective because it is believed to be more effective than external perspective MI. Using fMRI technology, Lorey, et al. observed that the internal perspective leads to a stronger activation of motor and motor-related areas than the external perspective (15). Several studies have investigated the effectiveness of MI using first person perspective imagery for rehabilitation purposes (16–18). Furthermore, in a review on MI training elements, Schuster, et al. reported, that in MI interventions with a positive results, internal perspective was more frequently used (4). Also, the Kinaesthetic and Visual Imagery Questionnaire-20, which is standardized questionnaire to assess MI ability of patients with sensorimotor impairments, emphasizes the first person perspective (19).

Only few studies investigated the explicit effects of MI perspectives on motor performance (13, 20, 21). However, the available findings on MI perspective do not support the notion that the use of an internal perspective is consistently superior to an external perspective (20, 21). In a sport context, White and Hardy (20) demonstrated that different MI perspectives could enhance different aspects of motor performance. External imagery was found to be more effective for learning and retention of a task and improvement of speed, whereas internal imagery supported accuracy of performance (20). Furthermore, there is evidence that suggests athletes rather take on an external perspective in open sports with complex movements (21, 22). So far, the basis of the recommendation to select the internal or the external MI perspective is inconclusive.

Less is known about how patients with sensorimotor impairments imagine movements. Studies on MI involving patients focused on MI ability, and reported fewer details concerning MI perspectives. Randhawa et al. described that patients with Parkinson's disease showed some difficulty to imagine axial movements (e.g. neck flexion) (23). Furthermore, Dettmers et al. demonstrated better MI ability for the third-person perspective compared to the first-person in patients after a stroke (24). Reports on patients' MI perspective preferences were embedded in two further studies. Schuster, Lussi (25) and Wondrusch and Schuster-Amft (26) described that the majority of the included patients with sensorimotor impairments preferred an external MI perspective for imaging gestures, if they were free to choose a MI perspective.

Several factors that seem to influence the choice of a certain MI perspective have been described in the literature. Mulder, Hochstenbach (27) point out the importance of age. Their results showed that healthy elderly participants (> 64 years) have some decline in the ability to imagine movements from the internal perspective. Based on this finding, they suggested assessing MI ability of a participant before starting a MI training program. An age related shift to the external perspective preference was supported by Kalicinski, Kempe (28) as well. Indeed, when MI capacity decreases with age, the therapeutic application of MI in motor rehabilitation becomes uncertain, especially with regard to neurorehabilitation, as the majority of patients belong to the older population (29). Furthermore, Mulder and colleagues discussed a possible association between the physical activity level and MI ability (27). It was proposed that a decreased physical activity level during aging could have a negative influence on the ability to imagine movements, particularly in relation to MI from an internal perspective (27).

There are further indications that healthy individuals as well as patients with sensorimotor impairments might change their MI perspective preference. Jiang, Edwards (30) reported that four out of 15 healthy participants aged between 19 and 29 years could not maintain their imagery perspective during brain scanning while imaging running up stairs. Seiler, Monsma (31) removed two participants from their study because they were switching MI perspectives. White and Hardy (20) had to exclude three out of 24 healthy participants (first-year sport health and physical education students) from their analysis due to the same reason. A change of preferred MI perspective in patients with motor impairments between two measurement sessions was further observed by Schuster, Lussi (32) when seven out of 73 patients changed their preferred MI perspective.

Apart from the MI perspective, the MI user may also choose between a visual and a kinaesthetic modality. The visual modality focuses on the visualisation of the movement, while the kinaesthetic modality focuses on the sensation of the movement (14). Kinaesthetic MI is commonly allocated to formation of an internal MI perspective. Dijkerman, Ietswaart (12) claimed that only an internal MI perspective could accompany kinaesthetic imagery. Jeannerod (33) proposed that internal MI involves kinaesthetic representations, while external MI refers to visual representation of an action. On the other hand, White and Hardy (20) and Callow, Roberts (13) suggested, that it might also be possible to experience kinaesthetic MI with external visual MI. In their study with sport students and healthy young adults, both study groups using either internal imagery or external imagery equally reported kinaesthetic sensation during MI. Unfortunately, MI perspective and MI modality are not always recognised as distinct elements of the technique. While several studies provide information on how participants were instructed to engage in MI, most of studies did not disclose the MI modality used by the participants (34, 35). Conversely, other studies make the distinction between MI modality but do not report the MI perspective (8, 14). Meanwhile there are investigations exploring brain activations ivolving these imagery modalities and perspectives (30, 31). They convey the importance of individual differences in the different conditions.

There seems to be contradictive evidence from regarding different best combinations of MI perspectives and modalities, thus it remains uncertain. To include MI in clinical practice and to develop useful instructions for MI training, it is important to understand the role of MI perspectives in a clinical setting.

Aim, research question, and hypothesis

The main aim of this study was to explore the spontaneous MI perspective selection over a certain time period leading to the following research question: What MI perspective do patients with sensorimotor impairments spontaneously select during visual and kinaesthetic MI over four measurement sessions?

The secondary aim was to evaluate whether MI perspective preference alters with age and if the physical activity level would influence MI perspective preference.

It was hypothesised that participants select an internal or external MI perspective in both visual and kinaesthetic imagery modalities, and that there might be changes of the MI perspective preference over time.

It was assumed that the imagined kind of movement itself could influence MI perspective preference, and that patients $\geq$ 64 years and being less active patients would prefer an external MI perspective spontaneously.

Methods

Design and setting

To evaluate spontaneous MI perspective preference a longitudinal study was conducted in a neuro-rehabilitation clinic in the Northwestern part of Switzerland. In- and outpatients were recruited between May 2015 and February 2016 and tested during four measurement sessions over a period of two weeks by one of three physiotherapists trained to carry out the standardised measurement procedure.

Selection criteria and standardised measurement procedure

Patients were eligible for participation if they were older than 18 years, had a first-ever clinically confirmed stroke (STR), or multiple sclerosis (MS), or Parkinson’s disease (PD), a minimum score of 19 on the Montreal Cognitive Assessment (MoCA), were able to sit stable on an armless chair, and to read and understand German. Patients with persistent pain were excluded. Potential candidates received oral and written study information and were given at least 24 hours to consider participation. After written informed consent, the four measurement sessions were scheduled within two weeks at least 48 hours apart to minimize the memory effect of the previous session (36).

Partients' personal characteristics and diagnosis-related characteristics were collected from patients' medical report and from the patients directly at the beginning of the first measurement session. Furthermore, patients were asked if they had previous experience with MI, as well as information about participants' cognitive function, handedness, level of independence in activities of daily living and physical activity level were gathered at the first measurement session. Only MI ability was assessed at all four measurement sessions.

Assessments description

Cognitive function: Cognitive ability was tested with the Montreal Cognitive Assessment (MoCA). That instrument screens for mild cognitive dysfunction in different cognitive domains (37). The lowest possible score is zero, the highest is 30. As the included population often presents mild cognitive impairment, the cut-off for inclusion was set at 19 (38). That scoring has been shown to have the highest diagnostic accuracy to discriminate between mild cognitive impairment and Alzheimer's disease (sensitivity 77%, specificity 80%)(38).

Handedness: The patients' dominant side was identified with the Edinburgh Handedness Inventory (EHI) (39). Participants were assessed by self-reported hand-use for 10 daily activities and the use of eyes and feet in one activity each.

Level of independence in activities of daily living: The Extended Barthel Index (EBI) is a reliable (0.96–0.99) and valid tool to rate the level of independence in daily life (40). The EBI includes 16 items representing different daily activities and cognitive ability (e.g. problem solving). Each item can be rated from zero (fully dependent) to four (fully independent). The total score can reach 64, with a higher score representing a higher level of independence.

Physical activity level: Physical activity level categories were defined based on the combination of recommendation from the Federal Office of Statistics - Swiss Health Survey and the handbook for Physical Activity Promotion in Primary Care (41, 42) as follows: inactive (not a noteworthy activity), partially active (at least 30 minutes per week at a moderate intensity or one day per week with vigorous activity resulting in sweating), active (at least 150 minutes at moderate intensity or 75 minutes with vigorous activity per week).

Patients were asked about all kinds of physical activity including leisure or sport activities, physical activity during work, household, and mobility. They reported the frequency and volume of physical activity twice: (a) for the last 12 months, and for (b) the years bevor the last 12 months and were assigned to a physical activity level category as described above.

MI ability assessments

The individual MI profiles were assessed using Mental Rotation (MR), Mental Chronometry (MC), and the German version of the Kinaesthetic and Visual Imagery Questionnaire-20 (KVIQ-20). Each of these assessments address distinct MI components (43) and should be combined (1). MR and MC were carried out in randomised order to reduce a learning effect.

1. MR of body parts is a cognitive task in which individuals imagine moving their body parts from their actual posture into that of the stimulus (44). The assessment focuses on accuracy referred to the number of correct answers over the total of presented stimuli. A total of 32 pictures of hand and feet (Recognise Flash Cards, Neuro Orthopaedic Institute, Adelaide City West, Australia) were presented in four different perspectives (back, palm or sole, radial and ulnar or medial and lateral side) in four various rotations (0, 90, 180, and 270 degrees) on a computer screen in a randomised order. Participants had to decide if the pictured hand or foot was shown from the right or left body side. The pictures remained on the screen until participants responded, but for a maximum of ten seconds each.
2. MC is a reliable method to examine the temporal structure of MI (45). It measures the temporal congruency between imagining and executing a movement. In the present study, participants performed a grasping and drinking movement with a plastic cup, both physically as well as mentally (46). The examiner demonstrated the task once and the participant was then allowed to practice the two different conditions. For both conditions (physical execution and MI), the movement began after the examiner gave a start command (“go”). The end of the movement was defined as moment when the cup first touches the table. For the MI condition, the end of the movement was indicated by the participant with a knock on the table or saying “stop”. The examiner manually timed the task with a stop-watch. The trial was repeated three times and average values across all trials were calculated. The ratio of the time needed for the mental and physical condition was calculated and used as final value for the MC.
3. The KVIQ-20 is valid and reliable questionnaire developed for the MI assessment in patients with sensorimotor impairments (19, 25). The aim of the KVIQ-20 is to determine the MI ability to visualise and feel the imagined movements using a five-point rating scale (1 = no image to 5 = image as clear as seeing, respectively 1 = no sensation to 5 = as intense as executing the movement). The KVIQ-20 includes 20 items (10 movements in each of visual and kinaesthetic subscales) representing simple movements of the head, shoulders, trunk, upper limbs, and lower limbs in a sitting position (Table 1). Upper and lower limb movements were evaluated on both body sides. Altogether, 17 movements were performed on each subscale with a possible scoring ranging from 17 (lowest) to 85 (highest). The standardised instructions and procedure contains four steps: (a) demonstration of the task by the examiner, (b) execution of the task by the patient with assistance from the examiner if necessary, (c) imagination of the task, and (d) rating of vividness or sensation by the participant. To allow the participants the spontaneous selection of their preferred MI perspective, the instruction of the KVIQ-20 to imagine the movements from the internal perspective was omitted.

Table 1
Items of the Kinaesthetic and Visual Imagery Questionnaire-20 and their movement type categories.

Visual	Kinaesthetic	Movements	Movement type
1V	1K	Bend and stretch the neck	Axial
2V	2K	Shoulder shrugging	Axial
3Vnd	3Knd	Lift arm forward completely	Upper limb, Proximal
4Vd	4Kd	Bend and stretch elbow	Upper limb, Distal
5Vd	5Kd	Thumb to fingertips	Upper limb, Distal
6V	6K	Bend the trunk forward	Axial
7Vnd	7Knd	Stretch out the knee	Lower limb, Distal
8Vd	8Kd	Move the leg to the side	Lower limb, Proximal
9Vnd	9Knd	Foot tapping	Lower limb, Distal
10Vd	10Kd	Turn the foot outwards	Lower limb, Distal

Legend

Items 3, 4, 5 after item 5, and items 7, 8, 9, 10 after item10 were tested on the other body side.

V = visual subscale, K = kinaesthetic subscale, d = dominant, nd = non-dominant.

MI perspective selection: For the evaluation of the MI perspective preference, two photographs of each item of the KVIQ-20 were shown to the participants: one photograph representing the internal and one representing the external perspective. After each KVIQ-20 task, participants were asked what photograph represents their preferred MI perspective. Examples of photographs representing the MI perspectives are presented in Fig. 1A-B. If a participant changed the MI perspective during imaging a movement of the KVIQ the answer “both” was noted down. In case a participant could not decide on one MI perspective, the answer “perspective selection not possible” was noted down. All items of KVIQ-20 were evaluated as above described first for the visual and subsequently for the kinaesthetic subscale.

Participants were instructed as follows e.g. for item ‘stretch out the right knee’:

The examiner showed the movement once.

Participants were instructed. ‘Sit upright with hands resting on your tights, stretch out your right knee once only.’

‘Return to the starting position. Now, imagine the movement, concentrate on the clarity of the image.’, for kinaesthetic imagery: ‘Concentrate on the intensity of the sensation.’.

The rating scale was visually presented only with descriptors and participants were asked to rate their vividness: 'How clear was the imagined movement?'; for kinaesthetic imagery to rate their sensation: 'How intense did you sense the imagined movement?'.

Two photographs representing the internal and the external point of view were shown and participants were asked: 'Which perspective did you use to imagine the movement?'.

Data processing and statistical analysis

The Statistical Package for the Social Sciences (Version 23.0 SPSS IBM, Armonk, USA) and Excel (Version 2011 for Mac, Microsoft Corporation, Redmond, USA) were used for all analyses.

Descriptive data were calculated including frequencies, mean and standard deviation, median and range where appropriate for patients' personal and assessment data. Patients were divided into three groups according to their diagnosis for transparent description of the study population: STR, MS, PD, but no comparison between these groups were carried out due to unequal sample sizes. Additionally, data were collapsed across all groups to describe the whole study population.

Patients (age range 24–91) were classified into three age groups: ≤44 years (adult), 45–63 years (middle aged), and ≥ 64 years (aged) based on the Medline MeSH classification of age categories (47). A cut-off at 64 years was set due to the findings of Mulder, Hochstenbach (27).

Frequency analyses on both visual and kinaesthetic subscales were conducted considering every single MI perspective selection across all KVIQ-20 items for the whole study population.

The frequencies of overall changes in the MI perspective and its consistency were analysed on the data from all four measurement sessions as follows:

1. The frequency of changes in one KVIQ-20 movement was analysed. There could be a maximum of three and a minimum of no changes over all four measurement sessions for one out of 17 KVIQ movements per patient. For all KVIQ movements there could be a maximum of 51 changes per subscale (102 for both subscales) and a minimum of zero. These changes were calculated and compared for each measurement session.
2. Based on the patients' amount of changes they were classified into five categories: (1) no changes, (2) few changes: one to 12 changes, (3) moderate changes: 13 to 25 changes, (4) frequent changes: 26 to 38 changes, and (5) very frequent changes: 39 to 51 changes based on cut-off percentages for the categories at 25%, 50%, 75% of all possible changes. Additionally, descriptive data were listed for patients of each change-behaviour category.

The KVIQ-20 items were subdivided into movement groups: axial, upper limb, lower limb, dominant side, non-dominant side, proximal, and distal (Table 1). The frequencies of selected MI perspectives on both visual and kinaesthetic subscales were calculated for all movement groups. The numbers of patients, who prefered the internal or external MI perspective or whose perspective selection was not constant, were listed for each patient group (STR, PD, MS).

Interanl MI perspective preference was considered if a patient used an internal perspective during imaging every item of a movement group. Likewise, external MI perspective preference was determined if a patient used an external perspective during imaging every item of a movement group. If a patients' preferred perspective altered at least once during imaging every item of a movement group, (e.g. patient imagined two out of three items of the axial movements using an external MI perspective, however, by imaging the remaining item, an internal perspective was preferred), altered MI perspective was determined.

Cross tables were used to compute the correlation of the MI perspective selection with age and activity levels. To examine the level of the correlation chi-square tests were applied using the Statistical Package for the Social Sciences (IBM Inc.) version 23.

Results

Between May 2015 and February 2016, a total of 58 patients were enrolled in the study and data from 55 patients were analysed (25 STR, 25 MS, 5 PD). Figure 2 presents the patient flow chart and reasons for drop out.

Patients’ characteristics and assessment scores

Descriptive parameters for patients’ personal data and assessment scores are displayed in Table 2.

Table 2
Patients’ descriptive data and assessment scores.

Group	Stroke n = 25	Multiple Slerosis n = 25	Parkinson's Disease n = 5	Total n = 55
Age (years)	63.3 ± 13.5 (42–91)	51.0 ± 11.9 (24–78)	70.4 ± 3.3 (66–75)	58 ± 14 (24–91)
Gender (female/male)	9/16	16/9	0/5	25/30
Experience with MI (yes/no)	6/19	5/20	0/5	11/44
Time since disease onset (months)	13.6 ± 35.3 (0.6–147.4)	156.0 ± 138.9 (0.7–573.2)	143.3 ± 99.0 (22.5–272.4)	90.1 ± 121.8 (0.6–573.2)
Handedness before diagnosis (right/left)	24/1	25/0	5/0	54/1
*National Institutes of Health Stroke Scale (max. 42) n = 11	3[a] (0–14)	na	na	na
*Expanded Disability Status Scale (max. 10) n = 23	na	6[a] (2.0-7.5)	na	na
*Hoen and Yahr Scale (max. 5) n = 4	na	na	3.5[a] (3–4)	na
Affected body side (right/left/both)	11/14/0	8/14/3	1/4/0	20/32/3
Extented Barthel Index (max. 64)	58.6 ± 6.8 (41–64)	57.3 ± 8.0 (36–64)	60.8 ± 4.3 (54–64)	58.2 ± 7.2 (36–64)
Activity level present (inactive/ partially active/ active)	4/8/13	0/18/7	2/1/2	6/27/22
Activity level previous (inactive/ partially active/ active)	0/3/22	0/8/17	0/1/4	0/12/43
Montreal Cognitive Assessment (max. 30)	24.7 ± 2.6 (19–29)	25.4 ± 2.1 (20–30)	22.6 ± 2.9 (19–27)	24.9 ± 2.5 (19–30)
KVIQ – 20 visual subscale total (max. 85)	59.0 ± 17.9 (27–85)	66.4 ± 13.9 (37–85)	59.4 ± 15.9 (33–75)	62.4 ± 16.2 (27–85)
KVIQ – 20 kinaesthetic subscale total (max. 85)	58.9 ± 18.2 (24–85)	57.0 ± 17.5 (17–85)	60.6 ± 12.3 (44–77)	58.2 ± 17.2 (17–85)
Mental Rotation (max. 32)	26.4 ± 4.6 (16–32)	27.9 ± 3.5 (17–32)	25.6 ± 4.4 (20–30)	27 ± 4.1 (16–32)
Mental Chronometry Quotient (imagery/ physical execution)	1.1 ± 0.3 (0.5-2.0)	1.0 ± 0.3 (0.7–2.4)	0.8 ± 0.2 (0.7–1.1)	1.0 ± 0.3 (0.5–2.4)

Legend

Numbers are listed as frequency or median[a] or mean score ± SD (range). *Value describing disease status/ quantifying disability caused by the disease. Activity level present considers last year, activity level previous considers before the last year.

KVIQ-20 = Kinaesthetic and Visual Imagery Questionnaire-20, MI = motor imagery, n = sample size, na = not applicable, max = maximum score

Patients' MI perspectives preference

The frequency analyses of the MI perspective selection for the visual and kinaesthetic subscales at each measurement session are shown in Fig. 3A-B. In general, the internal and external perspectives were selected over all four measurement sessions. In rare cases, patients were not able to select one of the MI perspectives.

On the **visual subscale** the external perspective was used in one third of the perspective selection (30.3%) at the first measurement session, which was reduced to one quarter of all selections at the three following measurement sessions (23.6%-26.2%). On the **kinaesthetic subscale** the internal perspective was more frequently selected (72.7–74%) over all four measurement sessions compared to the visual subscale.

Spontaneous selections of MI perspectives per movement group on the visual and kinaesthetic subscale assessed at the first measurement session are presented in Table 3.

Table 3
Frequency analysis of MI perspective selection in the KVIQ-20 according to movement groups on the visual and kinaesthetic subscales in the three patient groups.

N = 55	**Internal perspective**			**External perspective**			**Altered perspective**			
Movement group	STR	MS	PD	STR	MS	PD		STR	MS	PD
Axial (3)	6/ 7	9/12	0/1	4/4	9/3	2/1	Total	15/14	7/10	3/3
							2 movements internal perspective	6/7	2/5	1/1
Upper limb (6)	9/9	13/16	1/1	2/0	1/0	0/1	Total	14/16	11/9	4/3
							≥ 4 movements internal perspective	6/4	7/4	2/1
Lower limb (8)	9/11	12/15	1/2	1/1	1/1	0/2	Total	15/13	12/9	4/1
							≥ 6 movements internal perspective	4/2	7/5	1/1
Dominant side (7)	8/9	11/16	1/1	0/0	1/0	0/0	Total	17/16	13/9	4/4
							≥ 5 movements internal perspective	5/4	7/4	1/1
Non-dominant side (7)	10/10	11/16	1/1	0/0	2/0	0/0	Total	15/15	12/9	4/4
							≥ 5 movements internal perspective	3/3	6/4	0/1
Proximal (4)	10/10	10/15	0/1	1/3	4/1	0/1	Total	14/12	11/9	5/3
							3 movements internal perspective	2/3	7/4	3/1
Distal (10)	9/10	11/15	1/1	0/0	1/0	0/0	Total	16/15	13/10	4/4
							≥ 7 movements internal perspective	4/2	9/6	1/1

N = 55	Internal perspective			External perspective			Altered perspective			
All (17)	3/7	7/12	0/1	0/0	1/0	0/0	Total	22/18	17/13	5/4
							≥ 13 movements internal perspective	7/4	6/4	2/1

Legend

Numbers in brackets indicate the amount of items in the movement type group. Numbers in the columns represent the amount of participants, who chose a perspective (out of a total of 55 participants) during visual imagery/during kinaesthetic imagery.

In the column of altered perspective the second row represents patients with 75% of the movements in the movement group and amount of participants, who used an internal perspective at least in 75% of the movements.

KVIQ-20 = Kinaesthetic and visual imagery questionnaire long version, STR = Stroke, MS = Multiple sclerosis, PD = Parkinson’s disease, N = total number of participants.

MI perspective for KVIQ-20 movements

During kinaesthetic imagery, twice as much participants used an internal perspective for the KVIQ-20 movements (7 STR, 12 MS, 1 PD) compared to visual imagery (3 STR, 7MS, 0 PD). Only one participant imagined all visual imagery movements from an external MI perspective. The majority of the participants (80% during visual imagery, 64% during kinaesthetic imagery) altered their perspectives during the KVIQ-20 performance. Most participants used an internal perspective for more than 75% of the KVIQ-20 movements (Table 3). However, in individual cases, participants chose the external perspective more frequently than the internal perspective, e.g. 13 out of 17 movements were imagined from external and only four movements from internal MI perspective, or the choice of the MI perspective was evenly distributed.

MI perspective in different movement groups: Participants were more likely to choose the external MI perspective for axial or proximal movements. Figure 4 shows the MI perspective selection for different movement types.

Changes of the MI perspective selection

Changes of perspective preference including preference for each of the 17 KVIQ items for the visual and kinaesthetic subscale are displayed in percentages in Fig. 5A-B for all three patient groups at each measurement sessios. In general, more changes of MI perspective selection were observed in the visual subscale (measurement session 1 to measurement session 2: 27.6%) than in the kinaesthetic subscale (measurement session 1 to measurement session 2: 23%). MI perspective preference became more stable over the third and fourth measurement session.

MI perspective changes considering KVIQ-20 movements

Patients changed their MI perspective preference mainly for four items: lift arm forward completely, bend and stretch elbow, shoulder shrugging, bend and stretch the neck. Patients showed fewer changes for distal upper and lower limb movements: turn the foot outwards, foot tapping, moving thumb to fingertips. Additional file 1 provides detailed information about MI perspective changes considering the KVIQ-20 movements over the four measurement sessions.

Patient classification according to the perspective change categories

Table 4 provides an overview on the changing behaviour of all patients for the visual and kinaesthetic KVIQ subscales and for all three patient groups.

Table 4
Number of patients in the five categories of change-behaviour.

	Category	Number of changes	Visual subscale	Kinaesthetic subscale	Number of stable patients*
1	No changes	0	**8** (3, 5, 0)	**13** (5, 7, 1)	**7** (3,4,0)
2	Few changes	1–12	**24** (9, 12, 3)	**20** (7, 11, 2)	**16** (5, 9, 2)
3	Moderate changes	13–25	**17** (10, 7, 0)	**15** (9, 6, 0)	**12** (7, 5, 0)
4	Frequent changes	26–38	**3** (1, 1, 1)	**4** (2, 1, 1)	**2** (1,0,1)
5	Very frequent changes	39–51	**0** (0, 0, 0)	**0** (0, 0, 0)	**0** (0, 0, 0)
		Total	**52** (23, 25, 4)	**52** (23, 25, 4)	**37** (16, 18, 3)

**Legend: ***patients belong to the same change-behaviour category over all four measurement sessions. Numbers in brackets represent numbers of patients for each diagnosis group: stroke, multiple sclerosis, Parkinson’s disease.

In general, patients tend to remain constant regarding their MI perspective selection for the kinaesthetic subscale, 13 patients (no changes) and 24 patients (few changes) of the KVIQ-20 compared to the visual subscale with eight (no changes) and 20 patients (few changes), respectively. Furthermore, no patient was categorised with very frequent changes. Seven patients stayed constant and did not change their MI perspective selection at all: three patients in the STR group and four patients in the MS group.

Additional file 2 provides more information about patients's characteristics in the different categories of change-behaviour.

Association between MI perspective preference and age and activity level

Age groups and MI perspective preference:

Age group ≤ 44 years

11 patients (6 females) with a mean age of 40 ± 6 years included 2 STR, 9 MS patients with a mean KVIQ-20 score of 61.9 ± 15.7 on the visual subscale and 53.7 ± 14.4 on the kinaesthetic subscale.

Age group 45–63 years

22 patients (11 females) with a mean age of 53 ± 5 years included 10 STR and 12 MS patients with a mean KVIQ-20 score of 62.4 ± 17.1 on the visual subscale and 60.8 ± 18.1 on the kinaesthetic subscale.

Age group ≥ 64 years

22 patients (8 females) with a mean age of 72 ± 7 years included 13 STR, 4 MS and 5 PD patients with a mean KVIQ-20 score of 62.7 ± 16.1 on the visual subscale and 57.7 ± 17.8 on the kinaesthetic subscale.

A frequency analysis showed that patients in the age group ≥ 64 years used an external MI perspective more frequently and the internal less frequently during visual and kinaesthetic imagery compared to the younger age groups (Fig. 6). There was no correlation between age and perspective selection.

Physical activity level and MI perspective selection

The more active a participant was classified, the more likely he/she used an internal MI perspective. Participants, who were classified as ‘inactive’ over the last 12 month preferred an external MI perspective or altered between the internal and the external MI perspective. However, no statistically significant correlation could be shown between physical activity level and MI perspective selection. Non-significant trends were recognised in relation to every movement group. Figure 7A-C provides an overview on the non-significant trends for the axial, proximal, and distal movement types.

Discussion

The present study aimed to describe the spontaneous MI perspective selection over four measurement sessions in 55 patients with sensorimotor impairments. Results showed that patients selected both internal and external MI perspectives spontaneously when imagining items of the KVIQ-20. At every measurement session, in at least one quarter of all MI perspective selections the external perspective was chosen. The internal perspective was more likely used during kinaesthetic imagery than during visual imagery. In relation to movement type, external imagery was more likely used in axial and proximal movement types.

Over the four measurement sessions, patients became more consistent in their MI perspective preference. Patients changed their MI perspective mainly for the imagination of shoulder, arm and neck movements. Patients, who scored higher in the MI ability assessments as well as patients, who had a longer duration of their disease remained more constant for their MI perspective preference.

MI perspective preference

The KVIQ-20 does not provide an introduction to the concept of MI perspectives, but prompts users to imagine individual items frmom an internal perspective. Users with a preference on external perspective might find it difficult to use the internal one and they score lower on the KVIQ-20, resulting in an inaccurate MI ability. In further support of this argument, Butler, Cazeaux (48) also suggested to examine the relationship between preferred MI perspective and MI ability for the same reason. In the present study, patients were allowed to choose their preferred MI perspective spontaneously. Based on the high percentage of the external MI perspective preference in our patients, we recommend not to limit the MI perspective to the internal perspective during KVIQ-20. We would like to encourage researchers and clinicians to allow a spontaneous selection of the MI perspective during the KVIQ-20. This is in line with previous work by Schuster, Lussi (25), who recommend a pre-assessment of the patient's ability to distinguish between both MI perspectives before administering the KVIQ-20. In their study the first indications became obvious that patients might not only select the internal perspective if they are offered both the internal and external perspective (25). Scandola, Aglioti (49) desribed a deficit in MI ability in patients with spinal cord injury for the internal perspective imagery but not for the external. In addition to this, Dettmers, Benz (24) reported that patients after stroke showed better MI vividness for the external perspective than for the internal perspective. Jiang, Edwards (30) emphasized to use different perspectives even according to the location of the brain lesion, so that plasticity or activation of different areas could be supported. For example, it was proposed, that patients with partial brain damage in the temporal lobe should use external imagery to reinforce plasticity in the temporal lobe (30).

Furthermore, the complexity of the imagined movements might play an important role in MI perspective preference. Hardy and Callow (22) suggested that external imagery seems to be more effective strategy for learning a task that requires the production of complex movement pattern, e.g. the external perspective provides a driver information about different body parts, which would not be possible using an internal perspective. Butler, Cazeaux (48) hypothesized that patients after stroke may need to imagine functional movements, e.g. grasping a glass, subdivided in several movement phases. Here, the external perspective might be more efficacious.Scandola, Aglioti (49) desribed reduced MI ability in patient with spinal cord injury when they imagined a full-body movement compared to an upper extremity movement. Moreover, Kalicinski, Kempe (28) recommended, that the task complexity should be taken into account when MI ability is assessed, as complexity of a task might affect MI performance (a more difficult task leads to reduced MI ability score) (50).

In the present investigation, the majority of the patients altered their preferred MI perspective in the KVIQ-20 during the measurement session. This is similar to what Schuster, Lussi (25) and Wondrusch and Schuster-Amft (26) observed. The authors described, that study patients altered their MI perspective, and that the majority of patients used an external MI perspective. However, the findings might not be directly comparable. The differences to the present study findings might be attributed to the different assessments used to evaluate the MI perspective. Schuster, Lussi (25) and Wondrusch and Schuster-Amft (26) applied the computer- and video-based Imaprax software (51), which evaluates six complex, multi-joint upper limb gestures or activities of daily living, e.g. to applaud somebody, to write something, compared to the simple movements of KVIQ-20.

In the present study, the high percentage of altered MI perspective selection indicate that further exploration of a preferred MI perspective is profound for a better understanding of the participants' MI profile.

Altering MI perspective preference occurred not only within one session. Patients changed their preference between measurement sessions as well. Over four measurement sessions, several changes in the MI perspective selection from one to another session could be observed. Although, the number of changes decreased from the first to the later measurement session, it is difficult to state if patients showed a clear preference to one of both MI perspective options.

The high number of MI perspective changes implies that other factors might have an influence on the MI perspective preference and it might be helpful to evaluate the MI perspective before an MI training. One influential factor might be the environment, e.g. room brightness, auditory properties, setting, or odour.Callow, Roberts (13) suggested to investigate the relation of other sensory modalities such as auditory information to imagery perspectives. It might influence motor performance as well. In the present investigation, one patient mentioned that he had difficulties getting a clear MI perspective while sitting in a small room. Another patient mentioned that recruiting the internal perspective was easier when a noise, e.g. foot tapping, or an association with the movement triggered the imagination.

Several authors described that the use of both MI perspectives could be beneficial in different ways depending on the motor task to be imagined and what aspect of the performance should be enhanced (13, 50). White and Hardy (20) described that imagery from an internal perspective improved motor performance accuracy, thus imagery from an external perspective improved speed. Therefore, changes of MI perspective, or rather the ability to switch between the two MI perspectives would in this case be desirable or advantageous and could enhance the accuracy and speed of an imagined task. But these aspects of MI perspectives in motor learning should be further evaluated.

MI perspective preference considering KVIQ-20 items

The relation of the MI perspective preference to different movement types showed that axial and proximal movements of the KVIQ-20 were more often imagined using the external perspective. A possible explanation might be that for some movements, the external MI perspective provides information that would not be gained from an internal MI perspective (22), e.g. during bend head forward or lift arm forward. The moving body part itself is not or only partially visible from an internal perspective.

Further results of the present study indicated that the more proximal the executed body movement was the less consistent was the preferred MI perspective for the movement, e.g. lift arm forward completely, bend and stretch elbow, shoulder shrugging, bend and stretch the neck. Moreover, for the imagination of finger and foot movements the least MI perspective changes were observed. A potential reason could be the visibility of the movement or the extent of the body part to be imagined. During small distal movements, e.g. move thumb to finger tips, turning the foot outwards, every moving body part was visible for the patients from the start to the end of the movement. We assume that movement observation before imagination might have made the imagination easier and the same MI perspective could be selected during each measurement session. In contrast, during the movement lifting arm forward completely, the shoulder could not be seen throughout the complete movement execution. That might have resulted in a less constant MI perspective selection.

However, in the present study, imaging foot movements remained constant in the MI perspective selection and the least changes occurred over the four measurement sessions. That finding might suggest that prior a MI training the preferred MI perspective of a foot movement should be tested to introduce and explain the MI perspective.

MI perspectives in relation to MI modalities

The findings of the present study partially confirm the association between a kinaesthetic MI modality and an internal MI perspective described in the literature for patients younger than 64 years (12). Internal and external MI perspectives appeared to be independent of the kinaesthetic MI modality, supporting the view that a kinaesthetic sensation is possible during both an internal and an external MI perspective (13, 20).

For future investigations, we would like to encourage researchers to undertake neuroimaging studies with study populations other than stroke and healthy individuals and investigating different MI modes and MI perspectives in relation to age. A precise understanding of what neural structures on which activity level are involved during an internal and an external MI perspective remains uncertain (30).

MI perspective preference and affecting factors

Influence of age

Mulder et al. demonstrated a slightly better vividness in healthy elderly people over 64 years when using the external MI perspective (27). The result of the present study showed that patients with sensorimotor impairments over 64 years preferred to use external perspective more frequently than younger patient groups. Although this observation was not statistically significant, we consider it to be relevant as it could be an important aspect when using MI in neurological rehabilitation.

Influence of physical activity level

Mulder et al. described a tendency to use external MI at advanced age based on a lower level of own physical activity (27). Elderly people may be less active and spend more time watching others moving, resulting in a change in their point of view (27). Based on his propsed hypothesis the association between physical activity level and MI perspective selection was investigated, independent of age. No significant correlation between physical activity level and MI perspective selection variables could be shown. However, a distinctive trend to use the external MI perspective in 'inactive' classified participants became obvious. The experience of a certain movement type might be a better predictor of the MI perspective preference than physical activity level (volume and frequency). Hardy and Callow suggested that an external MI perspective is more beneficial for a task that requires the execution of a complex and form-based movement, e.g. karate (22). Thus, knowledge about type of activity may be relevant to explain the choice of a particular MI perspective (50).

Influence of further aspects

Further variables have been suggested to be crucial for MI perspective selection. The purpose of the task (e.g. to reach a cup) and the intervention (e.g. early motor skill development) should also be considered (31, 52). Using a functional, goal-oriented movement instead of the abstract movements of the KVIQ-20 to evaluate MI perspective might lead to different findings. If a movement is important and familiar to a person it may have an influence on the preferred MI perspective.

On the other hand, a functional movement may be challenging for patients with motor impairments. A patient may need to imagine phases of a movement separately, or imagine the movement in relation to other body parts (48). It is hypothesised that the external MI perspective may be more efficacious for patients in this case (24, 48).

Study limitations

The nature of MI makes an external control on MI performance difficult. Based on previous research, adding control measures e.g. electro-oculography or recording autonomic nervous system responses might be used as an objective technique to evaluate MI performance (53, 54). However, these options would provide only information if MI occurred or not, but the MI perspective used and the level of MI vividness would remain uncertain. In the present study, the evaluation of the MI perspective was based on the patients' verbal description. Most of the patients reported that the photographs used to express MI perspective were helpful and represented well both different perspectives. Additionally, as recommended by McAvinue and Robertson (55), an assessment battery including different assessments, was applied to evaluate different aspects of MI ability.

For the MI perspective selection only movements of the KVIQ-20 were investigated that included single joint movements performed and imagined in a sitting position only. However, for the evaluation of the MI perspective in patients with sensorimotor impairment is the KVIQ most suitable because it was specifically developed for that population. Furthermore, the KVIQ included proximal, distal, and axial movements of all body parts.

Finally, the relatively small sample size per patient group did not allow an in-depth examination of correlations among individual’s characteristics and MI perspective preference. Therefore, results were reported in a descriptive way only.

Conclusions

The present investigation of MI perspectives demonstrated that patients with sensorimotor impairments selected both the internal and external MI perspective spontaneously during visual and kinaesthetic MI over four measurement sessions within two weeks. These results indicate that MI modalities and perspectives should be taken into account independently by assessing MI abilities or the effect of MI.

Patients with sensorimotor impairments seem to change the MI perspective spontaneously between different visual and kinaesthetic MI tasks. Axial and proximal movements were more likely imagined using the external MI perspective compared to other movement types.

Patients became more consistent in their preferred MI perspective over time if they imagined finger, hand, and foot movements, had a longer disease duration, or were older. Foot and finger movements might be selected as an indicator for MI ability. MI perspective controllability over time and its influence on MI efficacy should be examined in future investigations.

Patients older than 63 years showed a tendency to select the external MI perspective more frequently while patients with reduced physical activity level declined to use the internal MI perspective. However, a statistically significant correlation between age or physical activity level with MI perspective preference could not be detected.

Our results of the spontaneous MI perspective selection and its changes in a longitudinal observation contributes to a better understanding how patients imagine a movement and how inconsistencies of the MI perspective occur with pursuing measurement sessions.

It could be hypothesised that a change of the MI perspective may be a desirable skill and should be included into a MI training to enhance motor output.

List Of Abreviations

MI Motor Imagery

STR Stroke

MS Multiple Sclerosis

PD Parkinson's disease

KVIQ-20 Kinaesthetic and Visual Imagery Questionnaire

PET positron emission tomography

fMRI functional magnetic resonance imaging

MoCA Montreal Cognitive Assessment

EHI Edinburgh Handedness Inventory

EBI Extended Barthel Index

MR Mental Rotation

MC Mental Chronometry

V visual subscale

K kinaesthetic subscale

d dominant

nd non-dominant

min. minimum

n/N sample size

PA physical activity

na not applicable

max. maximum score

ME measurement session

Declarations

Ethics approval and consent to participate

The study was approved by the local ethics committee (Ethikkommission Nordwest- und Zentralschweiz, 2015-172) and was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. All study patients gave their written consent to participate prior data collection.

Consent for publication

Consent for publication was obtained for Figure 1A-B.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request. All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests

The authors declare that they have no competing interests.

Funding

The study did not receive specific funding.

Authors' contributions

SG, RG and CSA designed the study and acquired data. SG and RG performed the data analysis and were responsible for interpretation, writing and revise the manuscript. CSA and ZS were responsible for data interpretation, manuscript review, and revision. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank all study participants for their time and support. We are grateful to Dr. Michael A. McCaskey, and Dr. Frank Behrendt for proofreading.

References

1. Di Rienzo F, Collet C, Hoyek N, Guillot A. Impact of neurologic deficits on motor imagery: a systematic review of clinical evaluations. Neuropsychol Rev. 2014;24(2):116–47.
2. Feltz DL, Landers DM. The Effects of Mental Practice on Motor Skill Learning and Performance: A Meta-analysis. J Sport Psychol. 1983;5:25–57.
3. Driskell JE, Copper C, Moran A. Does Mental Practice Enhance Performance? J Appl Psychol. 1994;79(4):481–92.
4. Schuster C, Hilfiker R, Amft O, Scheidhauer A, Andrews B, Butler J, et al. Best practice for motor imagery: a systematic literature review on motor imagery training elements in five different disciplines. BMC Med. 2011;9:75.
5. Decety J. The neurophysiological basis of motor imagery. Behav Brain Res. 1996;77:45–52.
6. Sharma N, Baron J-C, Rowe JB. Motor Imagery After Stroke: Relating Outcome to Motor Network Connectivity. Ann Neurol. 2009;66(5):604–16.

7. Jeannerod M, Frak V. Mental imaging of motor activity in humans. Curr Opin in Neurobiol. 1999;9:735–9.
8. Lotze M, Montoya P, Erb M, Hülsmann E. Activation of Cortical and Cerebellar Motor Areas during Executed and Imagined Hand Movements: An fMRI Study. J Cognit Neurosci. 1999;11(5):491–501.
9. Guerra ZF, Lucchetti ALG, Lucchetti G. Motor Imagery Training After Stroke: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Journal of neurologic physical therapy: JNPT. 2017;41(4):205–14.
10. Barclay-Goddard RE, Stevenson TJ, Poluha W, Thalman L. Mental practice for treating upper extremity deficits in individuals with hemiparesis after stroke. Cochrane Database Syst Rev. 2011(5).
11. Zimmermann-Schlatter A, Schuster C, Puhan MA, Siekierka E, Steurer J. Efficacy of motor imagery in post-stroke rehabilitation: a systematic review. J Neuroeng Rehabil. 2008;5:8.
12. Dijkerman HC, Ietswaart M, Johnston M. Motor imagery and the rehabilitation of movement disorders: an overview. In: Guillot A, Collet C, editors. The neurophysiological foundation of mental and motor imagery. Oxford: Oxford University Press; 2010. pp. 127–44.
13. Callow N, Roberts R, Hardy L, Jiang D, Edwards MG. Performance improvements from imagery: evidence that internal visual imagery is superior to external visual imagery for slalom performance. Front Hum Neurosci. 2013;7:697.
14. Guillot A, Collet C, Nguyen VA, Malouin F, Richards C, Doyon J. Brain activity during visual versus kinesthetic imagery: an fMRI study. Hum Brain Mapp. 2009;30(7):2157–72.
15. Lorey B, Bischoff M, Pilgramm S, Stark R, Munzert J, Zentgraf K. The embodied nature of motor imagery: the influence of posture and perspective. Exp Brain Res. 2009;194(2):233–43.
16. Page SJ, Levine P, Leonard AC. Effects of mental practice on affected limb use and function in chronic stroke. Arch Phys Med Rehabil. 2005;86(3):399–402.
17. Page SJ, Levine P, Leonard A. Mental Practice in Chronic Stroke Results of a Randomized, Placebo-Controlled Trial. Stroke. 2007;38:1293–7.
18. Schuster C, Butler J, Andrews B, Kischka U, Ettlin T. Comparison of embedded and added motor imagery training in patients after stroke: results of a randomised controlled pilot trial. Trials. 2012;13:11.
19. Malouin F, Richards CL, Jackson PL, Lafleur MF, Durand A, Doyon J. The Kinesthetic and Visual Imagery Questionnaire (KVIQ) for Assessing Motor Imagery in Persons with Physical Disabilities: A Reliability and Construct Validity Study. J Neurol Phys Ther. 2007;31(1):20–9.
20. White A, Hardy L. Use of different imagery perspectives on the learning and performance of different motor skills. Br J Psycol. 1995;86:169–80.
21. Yu Q-H, Fu ASN, Kho A, Li J, Sun X-H, Chan CCH. Imagery perspective among young athletes: Differentiation between external and internal visual imagery. J Sport Health Sci. 2015.
22. Hardy L, Callow N. Efficacy of external and internal visual imagery perspectives for the enhancement of performance on task in which form is important. J Sport Exercise Psychol. 1999;21:95–112.

23. Randhawa B, Harris S, Boyd LA. The Kinesthetic and Visual Imagery Questionnaire Is a Reliable Tool for Individuals With Parkinson Disease. J Neurol Phys Ther. 2010;34(3):161–7.
24. Dettmers C, Benz M, Liepert J, Rockstroh B. Motor imagery in stroke patients, or plegic patients with spinal cord or peripheral diseases. Acta Neurol Scand. 2012;126(4):238–47.
25. Schuster C, Lussi A, Wirth B, Ettlin T. Two assessments to evaluate imagery ability: translation, test-retest reliability and concurrent validity of the German KVIQ and Imaprax. BMC Med Res Methodol. 2012;12:127.
26. Wondrusch C, Schuster-Amft C. A standardized motor imagery introduction program (MIIP) for neuro-rehabilitation: development and evaluation. Frontiers in Human Neuroscience. 2013;7:477. doi 10.3389/fnhum.2013.00477.
27. Mulder T, Hochstenbach JB, van Heuvelen MJ, den Otter AR. Motor imagery: the relation between age and imagery capacity. Hum Mov Sci. 2007;26(2):203–11.
28. Kalicinski M, Kempe M, Bock O. Motor imagery: effects of age, task complexity, and task setting. Exp Aging Res. 2015;41(1):25–38.
29. Andreani T, Berrut S, Gazareth P, Hauri D, Kaeser M, Lieberherr R, et al. Swiss Statistics. In: Affairs FDoH, editor. Neuchatel: Federal Office of Statistics; 2014.
30. Jiang D, Edwards MG, Mullins P, Callow N. The neural substrates for the different modalities of movement imagery. Brain cognition. 2015;97:22–31.
31. Seiler BD, Monsma EV, Newman-Norlund RD. Biological evidence of imagery abilities: intraindividual differences. J Sport Exerc Psychol. 2015;37(4):421–35.
32. Schuster C, Lussi A, Wirth B, Ettlin T. Two assessments to evaluate imagery ability: translation, validity and test re-test reliability of the German KVIQ and Imaprax BMC Med Res Methodol. 2011;under review.
33. Jeannerod M. The representing brain: Neural correlates of motor intention and imagery. Behav Brain Sci. 1994;17(2):187–245.
34. Malouin F, Richards CL, Jackson PL, Dumas F, Doyon J. Brain activations during motor imagery of locomotor-related tasks: a PET study. Hum Brain Mapp. 2003;19(1):47–62.
35. Ross JS, Tkach J, Ruggieri PM, Lieber M, Lapresto E. The Mind's eye: Funtional MR Imaging Evaluation of Golf Motor Imagery. Am J Neuroradiol. 2003;24:1036–44.
36. Sandrini M, Brambilla M, Manenti R, Rosini S, Cohen LG, Cotelli M. Noninvasive stimulation of prefrontal cortex strengthens existing episodic memories and reduces forgetting in the elderly. Front Aging Neurosci. 2014;6:289.
37. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment. J Am Geriatr Soc. 2005;53(4):695–9.
38. Roalf DR, Moberg PJ, Xie SX, Wolk DA, Moelter ST, Arnold SE. Comparative accuracies of two common screening instruments for classification of Alzheimer's disease, mild cognitive impairment,

and healthy aging. Alzheimers Dement. 2013;9(5):529–37.

39. Oldfield RC. The assessment and analysis of handedness: The Edinburgh Inventory. Neuropsychol. 1971;9:97–113.
40. Prosiegel M, Böttiger S, Schenk T, König N, Marolf M, Vaney C, et al. Der Erweiterte Barthel-Index (EBI) - eine neue Skala zur Erfassung von Fähigkeitsstörungen bei neurologischen Patienten. Neurol Rehabil. 1996;1:7–13.
41. Bize R. Physical Activity Promotion in Primary Care. Zurich: Clinic of Medical University of Lausanne, Council of General Practitioners, League Vaudoises Against Cardiovascular Disease, Swiss Association of Sport Medicine, Institute of Social Medicine and Prevention University Zurich; 2012.
42. Storni M, Stamm H, Wiegand D, Lamprecht M. Exercise and Health. Neuchatel: Federal Office of Statistics.
43. Federal Office of Sport; 2014.
44. Guillot A, Collet C. Contribution from neurophysiological and psychological methods to the study of motor imagery. Brain Res Brain Res Rev. 2005;50(2):387–97.
45. Fiorio M, Tinazzi M, Aglioti SM. Selective impairment of hand mental rotation in patients with focal hand dystonia. Brain. 2006;129:47–54.
46. Malouin F, Richards CL, Durand A, Doyon J. Reliability of mental chronometry for assessing motor imagery ability after stroke. Arch Phys Med Rehabil. 2008;89(2):311–9.
47. Kobelt M, Wirth B, Schuster-Amft C. Muscle Activation During Grasping With and Without Motor Imagery in Healthy Volunteers and Patients After Stroke or With Parkinson's Disease. Frontiers in psychology. 2018;9:597.
48. Kastner M, Wilczynski NL, Walker-Dilks C, McKibbon KA, Haynes B. Age-specific search strategies for Medline. J Med Internet Res. 2006;8(4):e25.
49. Butler AJ, Cazeaux J, Fidler A, Jansen J, Lefkove N, Gregg M, et al. The Movement Imagery Questionnaire-Revised, Second Edition (MIQ-RS) Is a Reliable and Valid Tool for Evaluating Motor Imagery in Stroke Populations. Evid Based Complement Alternat Med. 2012;2012:497289.
50. Scandola M, Aglioti SM, Pozeg P, Avesani R, Moro V. Motor imagery in spinal cord injured people is modulated by somatotopic coding, perspective taking, and post-lesional chronic pain. 2017;11(3):305–26.
51. Olsson CJ, Nyberg L. Motor imagery: if you can't do it, you won't think it. Scand J Med Sci Sport. 2010;20(5):711–5.
52. Fournier JF. IMAGIX: Multimedia software for evaluating the vividness of movement-imagery. Percept Mot Skills. 2000;90(2):367–70.
53. Paivio A. Cognitive and motivational functions of imagery in human performance. Can J Appl Sport Sci. 1985;10(4):22–8.
54. Heremans E, Helsen WF, Feys P. The eyes as a mirror of our thoughts: quantification of motor imagery of goal-directed movements through eye movement registration. Behav Brain Res.

2008;187(2):351–60.

55. Collet C, Di Rienzo F, El Hoyek N, Guillot A. Autonomic nervous system correlates in movement observation and motor imagery. Front Hum Neurosci. 2013;7:415.
56. McAvinue LP, Robertson IH. Measuring motor imagery ability: A review. Eur J Cogn Psychol. 2008;20(2):232–51.

Figures

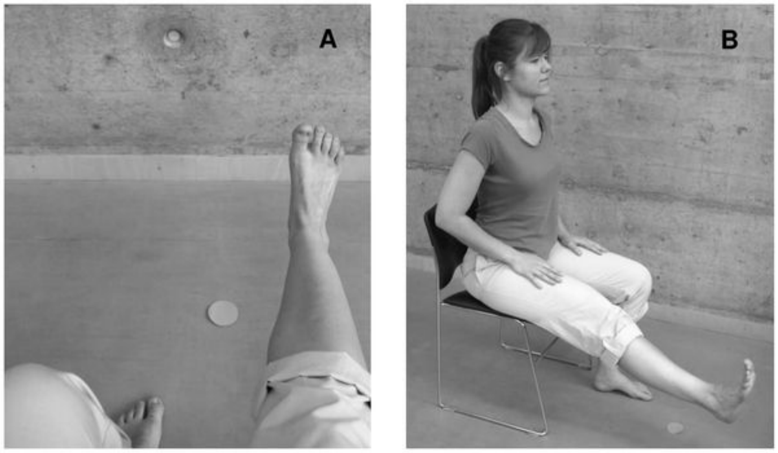

Figure 1 A-B

Figure 1

A-B. Motor imagery perspectives: (A) internal, (B) external.

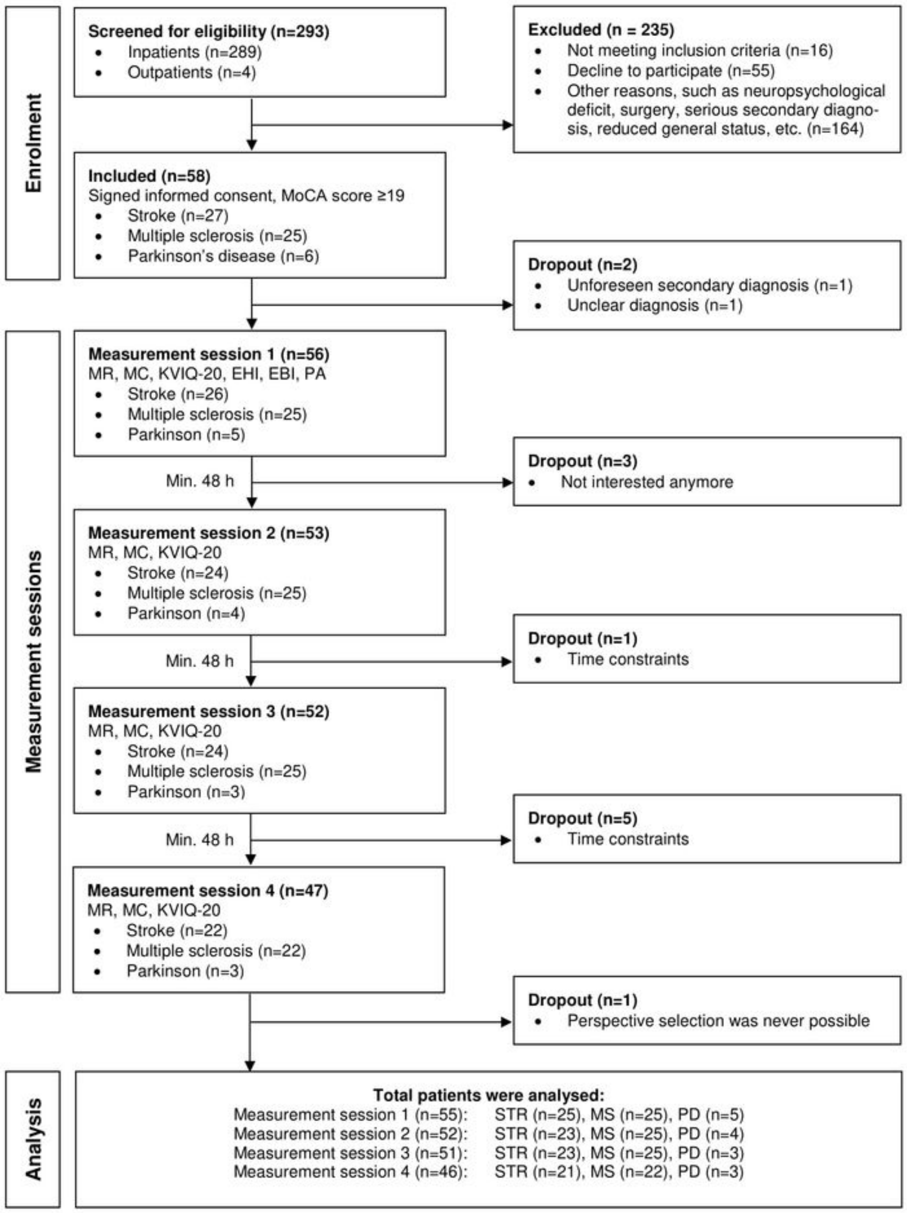

Figure 2

Figure 2

Patient flow chart. Legend: MoCA = Montreal Cognitive Assessment, KVIQ-20 = Kinaesthetic and Visual Imagery Questionnaire, MC = Mental Chronometry, MR = Mental Rotation, EHI=Edinburg Handedness Inventory, EBI = Extended Barthel Index, PA = questions about physical activity.

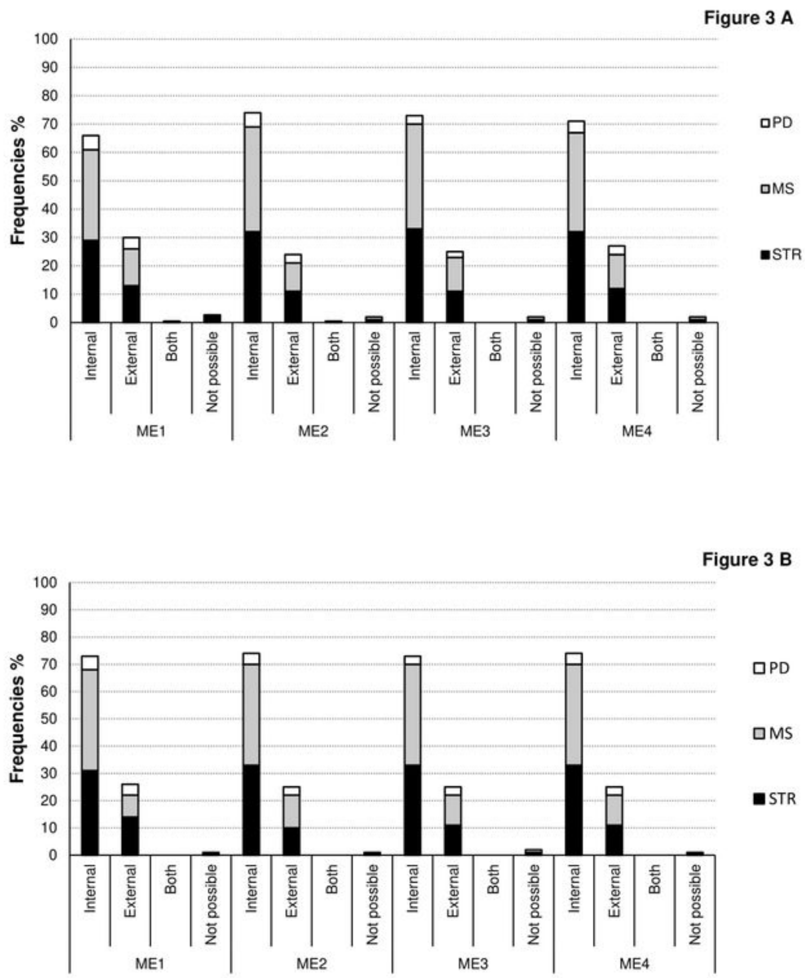

Figure 3

Frequencies of MI perspective preference in all items of KVIQ-20. Legend: On visual subscale (3A) and on kinaesthetic subscale (3B) over all measurement sessions for all patient groups. ME=measurement session, MS=multiple sclerosis, STR=stroke, PD=Parkinson's Disease.

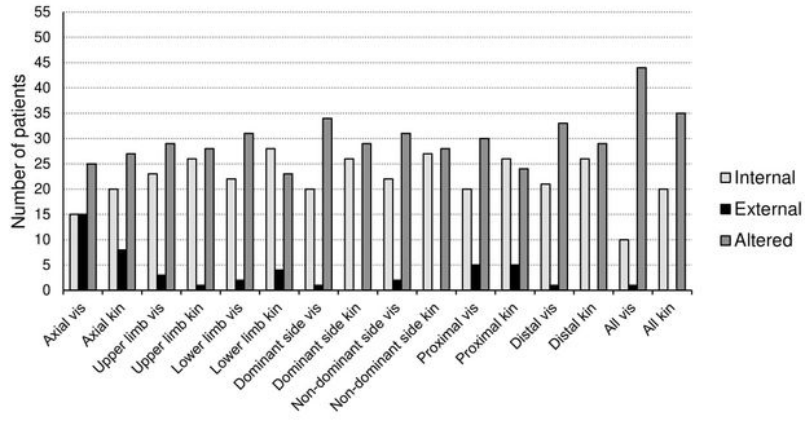

Figure 4

Figure 4

Comparison of MI perspective preferences in different movement type categories of the KVIQ-20. Legend: vis= visual, kin= kinaesthetic, KVIQ-20= Kinaesthetic and Visual Imagery Questionnaire-20.

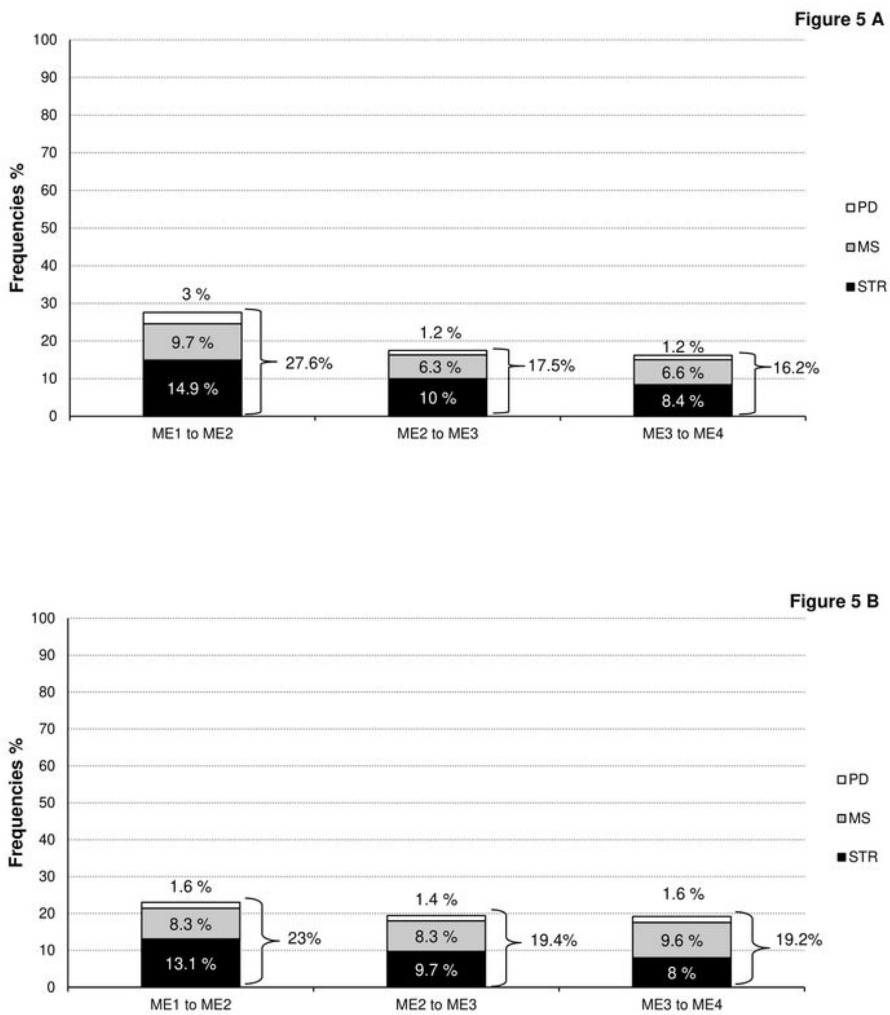

Figure 5

Frequencies of MI perspective changes. Legend: On visual subscale (5A) and on kinaesthetic subscale (5B) over all measurement sessions for all patient groups. ME=measurement session, MS=multiple sclerosis, STR=stroke, PD=Parkinson's Disease.

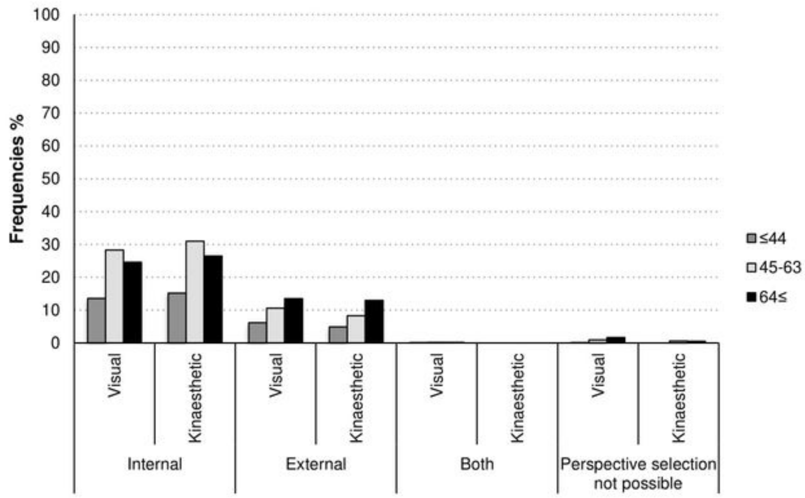

Figure 6

Figure 6

Comparison of MI perspective preferences in three age groups.

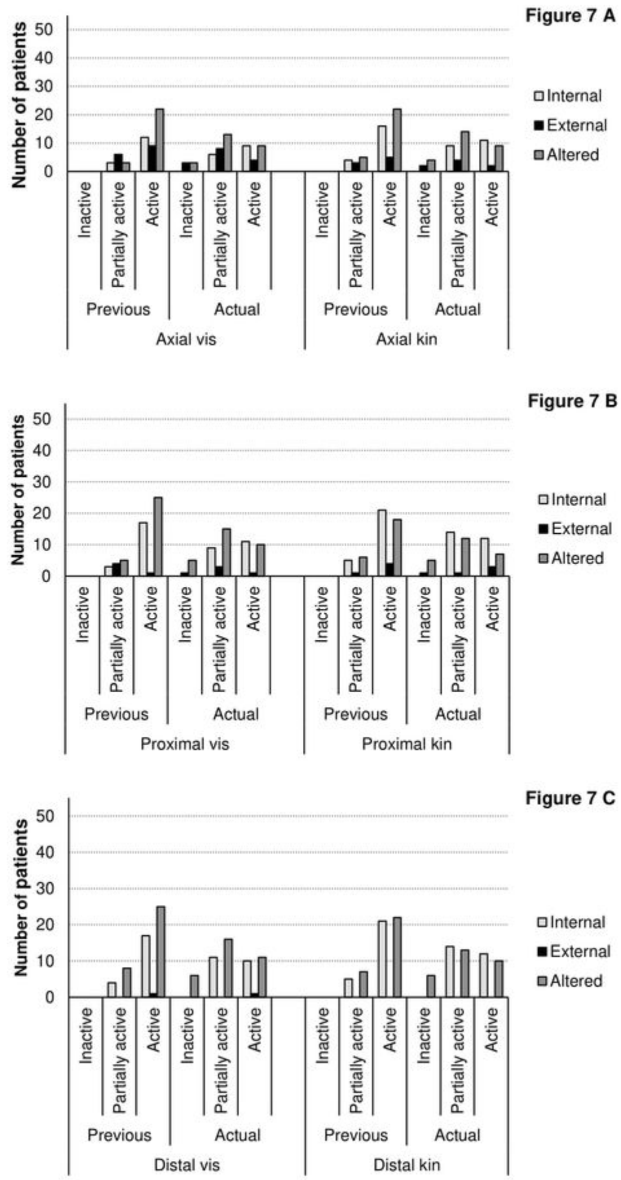

Figure 7

A-C. Comparison of preferred MI perspectives on the visual and kinaesthetic subscales in relation to actual and previous physical activity level. A = axial movement type B = proximal movement type C = distal movements type Legend: vis=visual subscale, kin=kinaesthetic subscale.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile2MIPPatientsinchangebehaviourcat.pdf
- Additionalfile1MIPMIperspectivechangesKVIQ20.pdf