Journal of Clinical Research & Case Reports

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Research Article

Cognitive Perspective Taking Ability in Patients with Madelung's Disease

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Abbreviations: NETs: cMRT: chronometric Mental Rotation Test; NCT: Number Connection Test; PSDQ: German Physical Self Description Questionnaire

Abstract

We investigated the mental rotation performance of patients with Madelung's disease compared to that of unaffected people with focus on the differentiation between object-based and egocentric transformations. Images of both - one Madelung's patient and one healthy person - were used as stimulus material. We assumed Madelung's patients to differ regarding their general appearance from healthy individuals. Since the representation of the own body is required especially in egocentric transformations, impairments of Madelung's patients should be more pronounced for egocentric transformations. Results showed that these patients were impaired in egocentric transformations when an image of both a Madelung's patient and a healthy individual was presented. A decreased performance in the object-based transformation was restricted to the use of a healthy human figure. This may be due to a stronger link between the body representation and egocentric transformations, which may indicate that the self-representation is altered in this clinical sample.

Keywords: Mental rotation; Object-based and egocentric transformations; Madelung's disease; Body representation

Cognitive Perspective Taking Ability in Patients with Madelung's Disease

It is the main goal of the present study to investigate, whether the appearance of the own body of patients with Madelung's disease, which is different from that of a healthy control group, has a detrimental impact on a specific spatial cognitive ability called mental rotation. The theoretical framework underlying this idea is the embodied cognition approach which claims that many cognitive processes that were originally thought to be exclusively cognitive seem to have a motor component [1]. In the case of mental rotation, spatial embodiment means that a bodily projection of the own body axes is fulfilled in order to solve perspective transformations in mental rotation [2].

Mental Rotation

Mental Rotation (MR) is defined as the process of imagining how a two- or three-dimensional object would look if rotated away from its original upright position [3]. In the classic chronometric Mental Rotation Task (cMRT) of Cooper and Shepard (1973) [4] two stimuli are presented simultaneously side-by-side on a screen and the participant has to decide as fast and accurately as possible if the right stimulus, presented under a certain angle of rotation, is the same or a mirror-reversed image of the left stimulus, the so called comparison figure. Mental rotation is a part of spatial intelligence and relates to cognitive processing speed [5].

In mental rotation two different classes of mental spatial transformations are contrasted: object-based and egocentric transformations [6]. Whereas in object-based transformations participants are required to perform a same-different decision by judging whether the right stimulus is the same or a mirror-reversed (different) version of the left stimulus, in egocentric transformations generally one single human figure raising one arm (left or right) is presented under different orientations. The participant is instructed to decide which arm is raised resulting in a left-right judgment [7]. Accordingly, in object-based transformations the observer's position remains fixed and participants mentally rotate the object in relation to the surrounding environment [8], whereas in egocentric transformations participants are required to mentally change their own perspective and thus imagine rotating their own body in order to make a decision. One crucial point is the question how motor processes influence the mental rotation performance. This leads to the embodiment cognition approach of mental rotation.

Embodiment of Mental Rotation

The embodied cognition approach claims that the usage of motor processes facilitates the solving of cognitive operations [9] and especially mental rotation. When using human bodies as stimulus material the mental transformation shares the same temporal and kinematic properties with actual body transformations [10,11,3]. Concerning egocentric and object-based mental rotations, there is some evidence that egocentric transformations seem to be embodied to a greater extent compared to object-based transformations [12-14]. One reason for this might be that egocentric transformations require the representation of the own body whereas object-based transformations are more similar to a covert manual rotation of an object [15]. Based on this assumption, the role of the body representation, the body image, while solving an embodied mental rotation task seemed to be important.

Embodied Mental Rotation and the Body Image

There is some evidence that patients with an impaired body representation show deficits in mental rotation performance. Using imaging techniques, Urgesi et al. (2011) [16] investigated patients with eating disorders (bulimia nervosa, binge eating) in both egocentric and object-based transformations. Their results showed that these patients are impaired in egocentric transformations requiring the transformation of their own body whereas no deficits in the object-based condition could be observed. The researcher concluded that a dysfunctional activity in the posterior parietal cortex is involved in the altered self-representation of patients with eating disorders. Interestingly, the parietal cortex is also involved in the mental rotation process [17]. Especially egocentric transformations are associated with an activation of the posterior parietal cortex [18,19].

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Received: July 21 2017; **Accepted:** July 31 2017; **Published:** August 03 2017

Citation: Kaltner S, Jansen P, Prantl L, Kuehlmann B. Cognitive Perspective Taking Ability in Patients with Madelung's Disease. J Clin Res Case Rep 2017; 1:103.

Obese patients are another example of subjects with impaired visuo-spatial performance [20]. Jansen et al. (2011) found that obesity affected the error rate when the rotation task was difficult. This conspicuousness was not observed when easier rotation tasks had to be solved. Besides, only object-based transformations were assessed. Given the alterations of body image in obese youth [21,22], we propose that there is a link between body image and the ability to transform the own perspective, which is required in egocentric transformations. This assumption is further supported by findings in athletes where a more positive body image compared to non-athletes was demonstrated [23]. The better performance of motor-experts compared to non-motor experts especially in egocentric transformations is well established [24].

The role of the body image must be considered from a differential point of view because body image is a multidimensional construct consisting of cognitive, behavioral (investment) and affective (satisfaction) components [25,26]. Concerning the cognitive determinant, the body is valued for its functional or aesthetic qualities. The behavioral-investment determinant aims at improving or maintaining a particular body dimension. Body satisfaction encompasses the affective evaluations made about particular body qualities [27].

Mental Rotation in People with Different Physiques

Facing this theoretical background, we investigated whether subjects who differ regarding their physique from healthy individuals are impaired in mental rotation performance. More specifically, we assessed patients with Madelung's disease and asked whether these patients show stronger impairments in egocentric transformations, which seem to involve the representation of one's own body [12,13]. Morbus Madelung - also known as multiple symmetric lipomatosis, Launois-Bensaude syndrome or benign symmetric lipomatosis - is a rare lipid metabolism disorder, where loose and un-encapsulated adipose tissue is localized symmetrically in multiple deposits of different parts of the body. Till now, the whole pathophysiology of this disorder and the uncontrolled lipomatous growth is unknown [28]. The incidence rate is higher in men than in women, especially in the Mediterrean area and the average age of incidence is approximately 60 years [29,30].

Summing up, the general appearance of these patients´ bodies is quite different to that of unaffected people. This leads to the consideration whether Madelung's patients do have an impaired body image and if so, whether they show impairments in an egocentric transformation task requiring the representation of their own body.

Aims and Hypotheses

This is the first study to investigate the cognitive functioning in patients with Madelung's disease. Since the representation of one's own body plays an important role in mental rotation performance [10,11], we hypothesized that Madelung's patients show a worse performance in mental rotation compared to healthy individuals expressed by higher reaction times and a lower accuracy rate. More specifically, we expected that impairments in patients with Madelung's disease are more pronounced for egocentric transformations compared to object-based transformations (Hypothesis 1). Besides, by using images of healthy participants and Madelung's patients as stimulus material, we investigated whether the kind of stimulus material affects the performance of both groups to a different extent (Hypothesis 2). More specifically, we wanted to see whether Madelung's patients show a different performance when representatives of the own sample are depicted as stimulus material, who are similar to the own body image, compared to the image of a healthy person.

Methods

Participants

Thirteen participants between 50 and 70 years participated in this study. The experimental group consisted of 7 patients (*mean age* = 64.1, *SD* = 7.9) with Madelung's disease recruited from the Clinic for Plastic-, Hand- and Reconstructive Surgery at the University Hospital in Regensburg. Six healthy participants were referred to as the control group (*mean age* = 61.3, *SD* = 15.1). According to the Mann-Whitney U-test, the groups (healthy *vs.* Madelung) did not differ regarding the age, gender, BMI or the amount of training sessions per week, which were assessed by the demographic questionnaire (all $p > .05$). Furthermore, there were no differences regarding the cognitive speed [31], the body image [32], or the amount of sportive training sessions per week, see Table 1. Sportive training sessions per week were measured due to the training effects in mental rotation performance [33]. Cognitive processing speed was analyzed because it is related to mental rotation performance [5]. None of the participants had performed a mental rotation test before and all participants signed informed consent for participation at the beginning of the experiment. The study was approved by the Independent Ethic Committee of the University of Regensburg (no. 08/117) and was conducted in full accordance with the Somerset amendment (South Africa, 1996) of the Declaration of Helsinki (1964).

Apparatus and stimuli

Number Connection Test [31]. The Number Connection Test was applied to measure cognitive processing speed. The test consists of four sheets of paper. On each sheet the numbers 1 to 90 are presented in a scrambled order in a matrix of 9 rows and 10 columns. The participants were required to connect the numbers as fast and accurately as possible in ascending order. The time needed to correctly connect the numbers was analyzed by averaging the time across the four sheets. The evaluation reveals NCT-scores, which are then transferred to corresponding cognitive speed values. The correlation between the Number Connection Test and standard IQ tests (e.g. Raven-SPM, CFT-30) ranges between r = .60 to .80 [34]. The internal consistency as well as 6-month test-retest reliability of the NCT is about .90 to .95. All test sheets were solved correctly without missing one number.

German Physical Self-Description Questionnaire [32]. This inventory is the German version of the PSDQ originally developed by Marsh, Richards, Johnson, Roche, and Tremayne (1994). It is a multidimensional, physical self-concept instrument designed to measure 11 scales: Strength, Body Fat, Activity, Endurance/Fitness, Sports Competence, Coordination, Health, Appearance, Flexibility, Global Physical Self-Concept, and Global Esteem. Stiller and Alfermann (2007) [35] evaluated psychometric properties of the German PSDQ and revealed that the German questionnaire is structurally equivalent to the original instrument having Cronbach's alpha values ranging from .67 to .92.

Mental rotation test

The cMRT was run on a laptop with a 17" monitor located approximately 60 cm in front of the participants. Stimuli were presented by using the software "Presentation" (Neurobehavioral Systems). There were 4 stimulus-conditions, two object-based and two egocentric ones, which were in turn split into two further categories, specifically "type of stimulus" (image of a healthy participant *vs.* image of a Madelung patient), thus resulting in: 1) object-based-healthy participants, 2)

Group	N	Sex	Age	BMI	PDSQ	Cognitive Speed	Trainings per week
Madelung	7	4 males, 3 females	64.1 (7.9)	30.4 (7.1)	3.2 (0.7)	90.3 (15.6)	0.3 (0.5)
Healthy controls	6	3 males, 3 females	61.3 (15.1)	25.9 (4.9)	1.5 (0.5)	95.7 (10.5)	1.4 (1.7)

Table 1: Means (Standard deviation) of demographic data body image, cognitive speed and sportive trainings per week.

object-based-Madelung's patients, 3) egocentric-healthy participants, 4) egocentric-Madelung's patients. Each condition was presented in a separate block, as shown in Figure 1. The order of the blocks was counterbalanced.

Object-based *vs.* egocentric transformations. For the object-based transformation two pictures of the same human figure were presented side-by-side in the center of the computer screen (see Figure 1, left). The left stimulus, the so-called comparison figure, was always displayed upright in the normal chirality and the right stimulus was presented in five different angular disparities of 0°, 45°, 90°, 135° or 180°, resulting in a same-different judgment. The right human figure was rotated in the picture plane in a clockwise direction. Half of the trials were pairs of identical objects and half were mirror-reversed images. Stimuli were presented in both front and back view. Hereby, the left and the right stimulus were always from the same view. That is, the view did not change within one trial but solely between trials.

In the egocentric condition only one human figure was presented in one of the orientations mentioned above (see Figure 1, right). This human figure raised either the left or the right arm. Thus, a left-right decision was required from the participant.

Stimulus Material

One participant from both the experimental and the control group was photographed. These photographs served as standard stimulus material for the whole experiment. The photographs were taken in a controlled setting with constant artificial lighting from a fixed distance. Afterwards, the photographs were edited with Adobe Photoshop software to ensure a completely white background. Therefore, in total four pictures were taken for each group (healthy *vs.* Madelung): 2 arm (left/right) × 2 view (front/back).

Procedure and experimental design

The individual test session, which lasted about 60 minutes, took place in a laboratory at the University Hospital Regensburg. First, the participants filled out the demographic questionnaire, followed by the German Physical Self-Description Questionnaire [32]. Next, the Number Connection Test [31] was conducted.

Afterwards, the cMRT was performed using a standardized task instruction. Regarding the two object-based conditions (healthy *vs.* Madelung), participants had to press the left mouse button (left-click) when the stimulus on the right side was identical (that is only rotated) to the comparison stimulus shown on the left side (same). In contrast to this, participants were required to press the right mouse button (right-click) when the stimulus on the right side was a mirror version of the left stimulus (different).

Figure 1: Exemplary healthy (a) and Madelung's (b) stimuli of the mental rotation paradigm.

Note. Left (a): Sample stimuli with an angular disparity of 180° as used in the object-based transformation task which demanded a same versus different decision. Right (b): Sample stimulus rotated at 45° as used in the egocentric transformation task which demanded a left arm versus right arm decision.

In the two egocentric conditions (healthy *vs.* Madelung), participants were instructed to press the right mouse button when the right arm of the figure was raised or the left mouse button in the case of the left arm (see Kaltner et al., 2014) [24].

In total, the cMRT consisted of four blocks. Each block began with ten practice trials. For correct responses a "+" appeared in the center of the screen and for incorrect responses a "-". However, feedback was solely given within practice trials. During the main trials, a pause of 15 seconds was given after every 20 trials. At the beginning of each trial, a fixation cross was presented for 1 second. Afterwards, the two human figures in the object-based transformation task or one single stimulus in the egocentric condition appeared and stayed on the screen until participants pressed the mouse button. The next trial began after 1500 ms.

The experiment contained four blocks of 32 experimental trials, resulting in 128 trials: 2 transformations (object-based/egocentric) × 2 stimulus types (healthy participants/Madelung's patients) × 4 angular disparities (0°, 45°, 90°, or 135°) × 2 repetitions of each combination × 4 stimuli per block (front *vs.* back view × left *vs.* right arm raised). The order of stimulus presentation within one block was randomized.

Statistical Analysis

Because of the small sample size, all statistical procedures were restricted to nonparametric techniques. The Mann-Whitney U-test for comparisons between two independent groups (healthy *vs.* Madelung) was used. In total, two separate analyses for "reaction time" and "accuracy rate", averaged over all angular disparities, were conducted. Back and front views were also analyzed separately, since stimuli presented frontally and thus facing the participants require an additional in-depth rotation to match the participant's orientation [8]. Thus, separately for the two dependent variables, and separately for back and front views and the four different conditions (s. above) we compared the two groups with the help of Mann-Whitney U-tests. Analyses were done across all degrees of angle of transformation. Reaction time was trimmed by +/- 2 standard deviations. Because we had directed hypotheses the one-tailed significance level was registered. Due to the fact that gender differences were often proved in mental rotation performance (e.g. Voyer, Voyer, & Bryden, 1995) [36], mean reaction time and accuracy rate were also analyzed with regard to possible gender differences using the Mann-Whitney U-test.

Results

Reaction time

Concerning reaction time, there was only a significant group-difference for the object-based images of the healthy participants when presented in the front view ($U = 9$; $z = -1.714$, $p < .05$). In this condition, patients with Madelung's disease showed a longer reaction time than healthy controls. All other conditions did not receive significance (all $p > .05$). All ranges are given in Table 2. There was no difference in the overall reaction time between males and females ($p > .4$).

Accuracy rate

Concerning accuracy rate there was a significant difference between healthy persons and Madelung's patients for the object-based images of the healthy participants when presented in the front view ($U = 5$; $z = -2.368$, $p < .05$) and for the egocentric images of healthy participants and patients when they were presented in the front view ($U = 0$; $z = -3.021$, $p < .05$ and $U = 4.5$; $z = -2.425$, $p < .05$). All ranges are given in Table 3.

Group	Object-based healthy stimuli		Object-based Madelung stimuli		Egocentric healthy stimuli		Egocentric Madelung stimuli	
	front	back	front	back	front	back	front	back
Madelung	8.71	8.00	7.00	7.14	7.00	8.14	7.86	6.14
Healthy controls	5.00	5.83	7.00	6.83	7.00	5.67	6.00	8.00
Asymp. Sig. (1-tailed)	.043	.183	.500	.443	.500	.125	.196	.196

Note: front = front view, back = back view; Asymp.Sig. = asymptotic significance (*p*-value)

Table 2: Mean range of reaction time for both groups.

Group	Object-based healthy stimuli		Object-based Madelung stimuli		Egocentric healthy stimuli		Egocentric Madelung stimuli	
	front	back	front	back	front	back	front	back
Madelung	4.71	6.29	6.29	6.79	4.00	5.43	4.64	6.64
Healthy controls	9.67	7.83	7.25	7.83	10.50	8.83	9.75	7.42
Asymp. Sig. (1-tailed)	.009	.225	.225	.412	.001	.054	.007	.351

Note: front = front view, back = back view; Asymp.Sig. = asymptotic significance (*p*-value)

Table 3: Mean range of accuracy rate for both groups.

Further analysis showed that the mean reaction time was not correlated with the mean accuracy rate (r_s = -.531, p> .06). Analyzing this correlation in more detail, the results showed that this holds not true for the correlation in object-based transformations between reaction time and accuracy rate within each type of stimulus (image of a healthy participant (r_s = -.566, p< .05 and image of a Madelungs patient (r_s = -.608, p< .05). Due to this finding, a possible speed accuracy trade off can only be excluded for the egocentric transformations, because there was no correlation between reaction time and accuracy rate within each type of stimulus (image of a healthy participant: r_s = -.018, p> .9; image of a Madelung's patient: r_s = -.405, p>.1). There was no difference in the overall accuracy rate between males and females (p > .7).

Discussion

The present study investigated the mental rotation performance of patients with Madelung's disease with focus on the differentiation between object-based and egocentric transformations. This study provides evidence that patients with Madelung's disease show impairments in mental rotation performance compared to non-affected individuals. More specifically, the present findings reveal that Madelung's patients showed a decreased performance in object-based rotations when images of healthy participants were used in the front view, this holds true for reaction time as well as accuracy measurement. However, concerning egocentric transformations, patients with Madelung's disease were impaired when images of both healthy persons and Madelung's patients were presented. This effect could only be detected in the accuracy rate. That is, concerning accuracy rate, in both stimulus-conditions the performance was affected in the egocentric transformation, whereas deficits in object-based transformations only occurred when images of healthy individuals were used (Hypothesis 1). Since performance is associated with the kind of stimulus material being used, we propose to conclude that there might be a possible link between this special syndrome, the stimulus material (Madelung *vs.* normal) and egocentric transformations (Hypothesis 2), which is discussed later in more detail.

Interestingly, differences between Madelung's patients and healthy participants solely emerged when stimuli were presented in the front view. Since this perspective requires an additional in-depth rotation of the own body to match the orientation of the stimulus, we conclude that this kind of simulative process seems to be impaired in patients with Madelung's disease. This consideration fits well with one further result of the present study: Madelung's patients showed deficits in both egocentric transformations (healthy- and Madelung-stimuli), whereas the decreased performance solely emerged in one object-based condition (healthy stimulus). This pattern indicates that there is a connection between this special syndrome and the ability to transform the perspective of one's own body. This assumption might suggest that the body image is affected in patients with Madelung's disease.

One further finding of the present study supports the notion of an impaired body image: When presenting Madelung's-stimuli, there was no group difference in object-based rotations, whereas in egocentric transformations Madelung's patients showed an impaired performance compared to the unaffected group when interpreting the accuracy rate. Since object-based rotations are more like a covert manual rotation of objects [15], compared to the perspective taking process in the case of egocentric transformations, a stronger activation of self-related thoughts could be assumed in egocentric transformations. This could explain why the perspective transformation of Madelung´s patients might be especially impaired when images of patients with a similar appearance are presented. This thought underlines the consideration of an affected bodily self in patients with Madelung's disease.

Compared to obese patients, where a dysfunctional body image was demonstrated by previous investigations [22], evidence regarding Madelung's patients is still missing. Since the present results are similar to the findings of Urgesi et al. (2011) [16], who investigated patients with eating disorders revealing a specific impairment restricted to egocentric transformations, an altered body representation in Madelung's patients should also be taken into account. In contrast to these samples of obese and anorexia nervosa patients, athletes show an improved performance especially in egocentric transformations [24]. This could be ascribed to the improved body representation of athletes [23] or the enhanced motor activity [7]. Long-term physical activity is related to a higher cognitive performance [37]. Since the amount of training sessions did not differ between Madelung's patients and healthy participants, we conclude that body image might be the crucial mediator.

One factor which is directly linked to the body image and should also be considered in patients with Madelung's disease, is the body dissatisfaction. According to the meta-analytic review of Hausenblas and Downs (2001) [23], the more positive body image of athletes compared to non-athletes is due to the finding that physical activity is associated with positive psychological characteristics such as increased self-esteem and decreased depressed mood, which are related to positive body image [38,39].

However, it still remains an open question why performance differences were found in the object-based condition using stimuli from a healthy individual in the front view. One might draw the conclusion that attentional processes might be relevant. There is evidence that attention is one of several sub-processes in mental rotation performance [40]. Object-based transformations are linked to a higher resource-allocation due to the presentation of two stimuli compared to one stimulus in egocentric transformations [19]. Since the appearance of patients with Madelung's disease is characterized by un-encapsulated adipose tissue [28], they do not correspond to the ideal body shape, which may lead to negative self-evaluation regarding the own body appearance. This interpretation is in line with the work of Gao et al. (2011) [41]. In this study, obese patients displayed an attentional bias towards overweight stimuli and avoided thinness stimuli due to ego-threatening dissonance of one's own body compared to the thin stimuli representing a societal ideal. An enhanced attentional focus towards the self can therefore distract attention-demanding resources away from the mental rotation process, especially addressing object-based transformations, where attention is required to a greater extent [19].

These results might lead to the conclusion that 1) a negative self-evaluation related to an altered body image might compete with attention-demanding resources which are important for the MR process, resulting in a decreased impairment in object-based transformations when being confronted with a thin ideal; and 2) a negative emotional self-evaluation may influence the body image in the sense of a top-down process resulting in a decreased performance regarding egocentric transformations. Since both egocentric conditions using Madelung's-stimuli and images of healthy individuals are affected, we tentatively propose that there is a stronger link between emotions and egocentric transformations compared to object-based rotations.

Evidence for the latter interpretation is provided by Reizer et al. (2011), who investigated patients with anorexia nervosa. According to their results, the altered body image is less influenced by bottom-up sensory input, but rather by top-down cognitive, semantic and affective representations (body dissatisfaction) [42-44]. The special link between emotions (body dissatisfaction) and the body image finds support by neuroimaging data: Anorexia nervosa patients are more emotionally involved when processing body-related stimuli, which is expressed by increased activity in the amygdala [45], while decreased neural activity was found in brain areas involved in perceiving body size and shape (e.g. posterior parietal cortex) [46,47]. Besides, Keizer et al. (2001) [48] found a positive relationship between insula activity and satisfaction ratings, which underlines a possible involvement of this region in body image satisfaction. Interestingly, egocentric transformations are also associated with the activation of the posterior parietal cortex and the insula [18,19]. The special link between emotions and egocentric transformations is further supported by behavioral data of Kaltner S, & Jansen P (2014) [24]. Results showed that the presentation of fearful stimuli enhanced especially egocentric transformations, expressed by a higher MR speed.

Facing this background, the special link between emotions (body dissatisfaction) and body image should be considered in the interpretation of the results of patients with Madelung's disease. Since, according to the embodied cognition approach, cognitive functioning is highly associated with emotions [49], the role of self-related emotions should be investigated in more detail in this context. Even though Madelung's patients did not differ from the healthy individuals regarding the Physical Self-Description Questionnaire (PSDQ)-score in the present study, it should be noted that this inventory was designed to measure physical self-concept and does not separate the cognitive, behavioral and affective components that comprise body image. Presumably, as argued above, the body dissatisfaction (affective determinant) should play a crucial role in mental rotation performance. In sum, the results of the present study revealed a decreased MR performance of Madelung's patients especially affecting egocentric transformations, which might be attributed to changes in body image. Since most of the conclusions are derived from samples showing similar result patterns, it illustrates the need for further scientific analyses addressing this clinical sample.

Limitations and Conclusions

For future investigations the various components of the term "body image" must be considered. Besides, when investigating the impact of body image on mental rotation performance, one could further ask whether the affective state itself is the determining component or whether cognitive evaluations related to this affective state in the sense of a resource-demanding allocation is contributing to the impaired mental rotation performance. To sum up, the Physical Self-Description Questionnaire seems to be not the appropriate instrument to assess the body image in this context. This is important for methodological implementations in future designs. There are numerous body image measures which vary depending on the aspect of body image is being assessed. An instrument focusing on both the body dissatisfaction as well as the cognitive component should be implemented in future investigations. Due to the small sample-size we could not analyze any gender differences dependent on group, and our results showed no overall gender differences. Furthermore, it was not possible to detect which effect the gender of the presented stimuli might have for the performance. The influence of the gender of the stimuli is neglected in embodied cognition on mental rotation until now. To conclude, the results of the present study underline that there are still many open issues in the research of the embodied cognitive functioning of patients with Madelung's disease.

Compliance with Ethical Standards

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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