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Does Body Awareness Influence Visual Spatial Intelligence?

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Abstract. The embodiment approach suggests that processes in the body influence cognitive performance. Due to this in the present study, female patients with high body awareness-elite athletes and patients with Anorexia Nervosa- as well as healthy controls performed a mental rotation task with different kinds of stimuli. Mental rotation is the ability to imagine objects from different perspectives. The results show that both experimental groups revealed a better mental rotation performance than the control group in form of faster reaction times. This result is independent of the kind of stimuli, i.e., if the mental rotation requires the transformation of the self (egocentric) or the object (object-based). We further found that BMI and IQ correlated with reaction time. Because there was no difference between the elite athletes (positive body awareness) compared to the patients with Anorexia Nervosa (negative body awareness) the results suggest that any occupation with the body relates to visual spatial intelligence. This result is discussed regarding its importance in the educational context.

Keywords: Mental Rotation; Anorexia Nervosa; Embodiment; Elite Athletes.

Introduction

The embodied cognition approach claims that many cognitive processes that were formerly defined as purely "cognitive" are also deeply rooted in body-related experiences with the environment (Wilson, 2002). The main issue of the present study is to investigate the embodied nature of a specific cognitive ability called mental rotation in participants from whom we know that they are deeply occupied with their body, elite athletes as well as patients with Anorexia Nervosa. More specifically, we focused on two transformation types in mental rotation, object-based and egocentric transformations. In contrast to object-based transformations, egocentric transformations require the representation of the own body to solve the task. Consequently, participants who are occupied with their body due to training or during restricted eating to lose weight, should show a better egocentric mental rotation performance compared to object-based ones. It has to be investigated, if there is a difference between participants who have a positive picture of their body (elite athletes) or those who show a negative one.

Mental rotation

Mental rotation is a specific visuo-spatial ability. This involves the process of imagining how a two- or three-dimensional object would look if rotated away from its original upright orientation (Shepard & Metzler, 1971). In a classic chronometric mental rotation test two stimuli are presented simultaneously on a screen. In most cases, the left stimulus is presented in an upright position and participants have to decide as fast and accurately as possible if the rotated right stimulus is the same object, that means non-mirrored version or if it is not the same, i.e., a mirror-reversed version, of the left stimulus. Thereby angular disparities are systematically varied and reaction times and accuracy rate are assessed as dependent variables.

In mental rotation two different types of mental transformations are contrasted: object-based and egocentric transformations (Zacks, Mires, Tversky, & Hazeltine, 2000). In an object-based transformation the observer's position remains fixed, in an egocentric transformation tasks participants are asked to mentally change their own perspective. That means that they have to imagine rotating their own body in order to make a decision (Devlin & Wilson, 2010). That is, there are two different reference frames: In contrast to object-based transformations where objects must be judged in relation to each other, the reference frame in egocentric transformations is the own body. Each transformation type depends on the type of judgment that has to be made: In the case of an object-based transformation two images are typically presented next to each other. In this case participants are asked to perform a same-different judgment. An egocentric transformation is often evoked by the presentation of a single human stimulus, for example a human figure raising one arm (left or right) appearing at varying orientations. The participant has to decide which arm is outstretched, thus resulting in a left-right judgment (Steggemann, Engbert, & Weigelt, 2011). However, according to Amorim, Isableu, and Jarraya (2006) not only the type of the judgment, but also the stimulus type induces spatial transformations.

Evidence from behavioral data confirms the view that object-based and egocentric transformations are implemented by two different processing systems. Regarding response time patterns, the typical increase of response times with increasing angular disparity is more evident in object-based transformation tasks than in egocentric ones (Jola & Mast, 2005). Moreover, Zacks, Mires, Tversky and Hazeltine (2002) did not observe any relationship between mental rotation time and angular disparity in a left-right mental rotation task.

Embodiment of mental rotation

According to Wilson (2002) the embodied cognition approach implies that many cognitive processes that were originally thought to be purely cognitive seem to have a motor component. That is, the use of motor processes facilitates the solving of cognitive problems (Jeannerod, 2003). In the case of mental rotation there is evidence that motor processes play an important role. Based on several findings using human bodies as stimulus material it was shown that the mental transformation shares the same temporal and kinematic properties with actual body transformations (Parsons, 1987, 1994; Shepard & Metzler, 1971). In other words, mental rotation of body parts is performed through the observer's simulation of rotational movements (Parsons, 1994). Shepard and Metzler (1971) interpreted the linear increase of reaction times as a hint that the process of mentally rotating an object is analogous to the manual rotation of an object. This assumption was supported by the work of Wexler, Kosslyn, and Berthoz (1998) and Wohlschläger (2001).

There is plentiful literature that egocentric transformations are embodied to a higher extent than object-based transformations (Gallese, 2003, 2005; Kessler & Rutherford, 2010; Kessler & Thomson, 2010; Lorey et al., 2009), which might be due to the fact that egocentric transformations depend more on the representation of the own body than object-based transformations.

Embodiment of mental rotation in participants with higher body awareness

Until now, there are only studies, which investigate an improved mental rotation performance with elite athletes. The definition of an elite athlete is very difficult (Swann, Moran, & Piggott, 2015); in the present study we define athletes as persons who train around 4 times a week. Jansen and Lehmann (2013) found that gymnasts show a better mental rotation performance than people who do not do any sports or play soccer. But not only elite athletes but also normal sport students show a better mental rotation performance than for examples educational students (Pietsch & Jansen, 2012). Furthermore, a study revealed that elite athletes who completed daily practice of a combat sport (fencing, judo, and wrestling) showed a higher mental rotation performance than elite runners (Moreau, Mansay-Dannay, Clerc, & Guerrien, 2011). It is suggested that the enhanced motor activity improves the mental rotation process. But there is also another possible explanation. This is the occupation with the body, which comes along with heightened body awareness. Through this the embodiment of cognitive processes is facilitated.

Another subgroup who seems to have higher body awareness are patients with Anorexia Nervosa. Anorexia Nervosa is a serious somatic and psychic illness that affects 0.5-1.0 women during their lifetime (Ludson, Hirpi, Pope, & Kessler, 2007). Patients with Anorexia Nervosa have a BMI below 19. Because the patients feel fatter than they are, they refuse to eat. One of the major clinical symptoms is the occupation with the body, the dissatisfaction with the body and the distortions in body image perception (Garfinkel, Moldofsky, Garner, Stanger, & Coscins, 1978). Concerning the cognitive functions of patients with Anorexia Nervosa, the results are diverse. On the one side, it was shown that patients with Anorexia Nervosa scored higher in a visual search paradigm than healthy controls (Southgate, Tchanturia, & Treasure, 2008). On the other side it was shown that patients with Anorexia Nervosa showed impaired executive functions (Weider, Indredavik, Lydersen, & Hestad, 2015). Up to now, there is no study, which investigates the mental rotation performance in patients with Anorexia Nervosa.

Goal of the present study

It is the main goal of this study to investigate the performance in an object based and egocentric mental rotation task with participants with different body awareness. We assume that elite athletes as well as patients with Anorexia Nervosa, who both have a lower BMI than the normal control group, are more occupied with the body than control subjects. Due to the theoretical background the following hypotheses could be established:

1. Elite athletes show a better mental rotation performance than the control group either due to their motor activity or their positive body awareness.
2. Patients with Anorexia Nervosa show a worse mental rotation performance then the control group due to their negative body awareness.
3. Furthermore an interaction with the type of stimuli is expected. It is assumed that participants with a higher body awareness show a better mental rotation performance with egocentric compared to object–based transformations.

Methods

Participants. Fifty-six females between 16 and 30 years of age participated in the study. There were 19 elite athletes (*mean age*: 22.84, *SD* = 2.61), 20 patients with Anorexia Nervosa (AN; *mean age*: 22.50, *SD*= = 4.49) and 17 healthy control women (*mean age:* 22.88, *SD* = 2.50). In this study, Elite athletes were defined by at least 4 sport units per week and the patients with Anorexia Nervosa participated in a therapeutic programme for eating disorders. The elite athletes differed with 4.78 sport units per week significantly from the patients with AN and the control women, see Table 1. However, it should be noted that the sports behaviour of the patients with AN was limited and controlled by the therapists. The groups did not differ in their age, but in the IQ and the BMI as noted in Table 1. The IQ was measured with the Number Connection Test, ZVT (Zahlenverbindungstest, ZVT; Oswald & Roth, 1987) by measuring cognitive speed. This test consists of four sheets of paper. On each sheet, the numbers 1 to 90 are presented in a mixed order in a matrix of 9 rows and 10 columns. The participants had to use a pen to connect the numbers as fast as possible in ascending order. The number of correctly connected numbers was analyzed for each participant.

ZVT-scores were converted into IQ values. The correlation between the ZVT and standard IQ tests is about r = .60 to .80 (Vernon, 1993). The ZVT is the equivalent to the Trail Making Test A (Reitan, 1956). The test administration, including instructions and practice matrices, takes about 20 minutes. The BMI, which was calculated for each female, is defined as the body mass [kg] divided by the square of the body height [m]. Participants were recruited through advertisements in the local newspapers and at the campus. The patients with Anorexia nervosa were recruited by contacting a therapeutic centre for eating disorders. All participants gave informed consent for participation according to the declaration of Helsinki.

Table 1: Univariate *F*-tests for the factor "group" (Mean RT and SD) concerning age, IQ, BMI and sport units.

	Group								
	Elite athletes		Patients with AN		Control group				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η_p^2
Age	22.84	2.61	22.50	4.49	22.88	2.50	0.05	.950	.00
IQ	122.74	12.64	110.15	11.28	106.76	14.00	69.73	.001	.24
BMI	20.98	1.74	18.08	2.09	22.69	3.28	8.22	< .001	.40
Sport units	4.79	0.37	1.40	1.69	0.53	0.72	25.28	< .001	.49

Apparatus and Stimuli

Mental rotation test (see also Jansen & Kaltner, 2014)

For the mental rotation task, the experiment was run on a laptop with a 17" monitor located approximately 60 cm in front of the participant. The test was adapted from the work of Steggemann et al. (2011). There were three different experimental stimuli, 1) frontal view of two female people with either the left or the right arm extended (body figure object based: BFO), 2) front and back view of one female person with either the left or right arm extended (body figure egocentric: BFE), and 3) the letters R and F, see Figure 1.

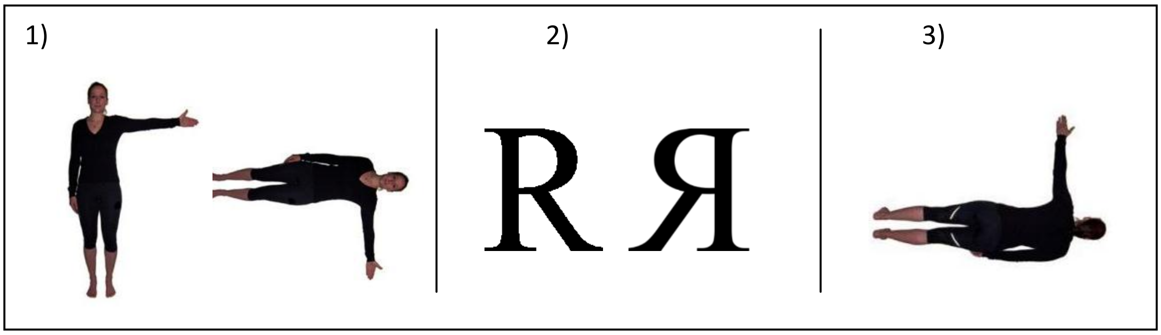

Figure 1: Examples of the three different stimuli, 1) body figures object based (BFO), 2) letters, and 3) body figures egocentric (BFE)

In the letter and BFO condition two drawings of the same kind of stimuli were presented simultaneously with an angular disparity of 0°, 45°, 90°, 135° or 180°. The right stimulus was rotated compared to the left stimulus, the so called "comparison figure". Half of the trials were pairs of identical objects and half were mirror-reversed images. The letters were black and the human figures were wearing black clothes. Contrary to the letter and BFO condition in the BFE condition only one figure was presented in the rotation angles mentioned above. This figure raised either the left or right arm. All stimuli were rotated in the picture plan.

Procedure

The individual test sessions lasted about 60 minutes in total. They took place in a laboratory at the University of Regensburg or at the therapeutic centre for eating disorders (TCE) in Munich. Instructions of the mental rotation tests were standardized. In the BFO and letter conditions participants had to decide as quickly and as accurately as possible if the stimuli were either the same that means not mirror-reversed, or different, which means mirror-reversed to the comparison stimulus (shown on the left side). Participants had to press the left mouse button (left-click) when the two stimuli were "same" and the right mouse button (right-click) when the two stimuli were "different". When the stimuli from the BFE condition were presented, participants had to decide if the figure raised the right or the left arm. Participants had to press the left mouse button (left-click) when the figure raised the left arm and the right mouse button (right-click) when the right arm was raised.

Each trial began with a fixation cross for 1 second. After that, the pair of stimuli appeared and stayed on the screen until participants answered. Feedback was given for 500ms after each trial: In the case of a correct response a "+" appeared in the centre of the screen and in the case of an incorrect response a "-" appeared. The next trial began 1500ms thereafter. Each type of stimulus was presented in a separated block which was preceded by eight practice trials. There were 80 trials in each of the three blocks (without practice trials). After every ten trials within each block a pause of 15 seconds was given before the next ten trials were administered. The next block started after a break of around one minute. The presentation of the three blocks was randomized.

Each participant performed 3 blocks of 80 experimental trials, resulting in 240 trials: 3 stimulus types (BFE vs. BFO vs. objects) * 2 trial types (same vs. different) * 5 angular disparities (0°, 45°, 90°, 135° or 180°) * 4 repetitions of each combination. In each block the order of the presentation of the stimuli was randomized.

Statistical analysis

Two repeated measure analyses of variance were conducted with "stimulus type" (BFO, letters, BFE), "group" (elite athletes, control group, patients with Anorexia Nervosa) and “angular disparity” (0°, 45°, 90°, 135°, 180°) as factors and “reaction time” (RT) and “accuracy rate” as dependent measurements.

A correlation as well as a regression analysis was conducted between the performance in the mental rotation task and the IQ and BMI. However, this was done only for the reaction/response times because a group effect was found for this dependent variable only (see below).

Results

Mental rotation: reaction time (RT)

The analysis of variance showed a main effect for the factors “stimulus type”, $F(2,106) = 16.41$, $p < .001$, $\eta_p^2 = .24$, “angular disparity”, $F(4,212) = 316{,}329$, $p < .001$, $\eta_p^2 = .856$, and “group”, $F(2,53) = 5.88$, $p < .01$, $\eta_p^2 = .182$. Furthermore there were significant interactions between the factors “group” and “angular disparity”, $F(8, 212) = 3.85$, $p < .001$, $\eta_p^2 = .127$, as well as an interaction between “stimulus type” and “angular disparity”, $F(8, 424) = 6.29$, $p < .001$, $\eta_p^2 = .106$.

The interaction between “group” and “angular disparity” is displayed in Figure 2. It shows that the three groups did not differ at an angular disparity of 0°, but with all other angular disparities. Multiple t-tests with a Bonferroni corrected significance level were performed. They showed that at an angular disparity of 45° both the patients with AN (*M*=836.88ms, *SD*= 125.65), $t(35)=2.681$, $p=.011$, and the elite athletes (*M*=813.36ms, *SD*=210.03), $t(34)=-2.404$, $p=.022$, differed from the control group (*M*=970.54ms, *SD*=175.93), whereas elite athletes and patients with AN did not differ significantly, $t(37)=-.416$, $p=.680$. For an angular disparity of 90°, the reaction times of elite athletes (*M*=897.36ms, *SD*=226.22) and the patients with AN (*M*=919.11ms, *SD*=140.60) differed from the ones of the control group (*M*=1132.56ms; *SD*=278.01), $t(34)=-2.798$, $p=.008$, and $t(35)=-3.015$, $p=.005$. Concerning the angular disparity of 135°, compared to the control group (*M*=1071.43ms; *SD*= 168.59), there was a significant difference between both the patients with AN (*M*=1288.44ms; *SD*=271.34), $t(35)=-2.296$, $p=.005$, and the elite athletes (*M*=1053.01ms; *SD*=294.25), $t(34)=-2.486$, $p=.018$, whereas patients with AN and elite athletes did not differ, $t(37)=-.241$, $p=.811$. At an angular disparity of 180° there was only a significant difference between elite athletes (*M*=1372.99ms; *SD*= 329.45) and the control group (*M*=1767.84ms, *SD*= 436.35), $t(34)=-3.084$, $p=.004$. There was no difference between the performance of the elite athletes and the patients with AN (*M*=1563.42ms; *SD*=223.95), $t(37)=.437$, $p=.935$.

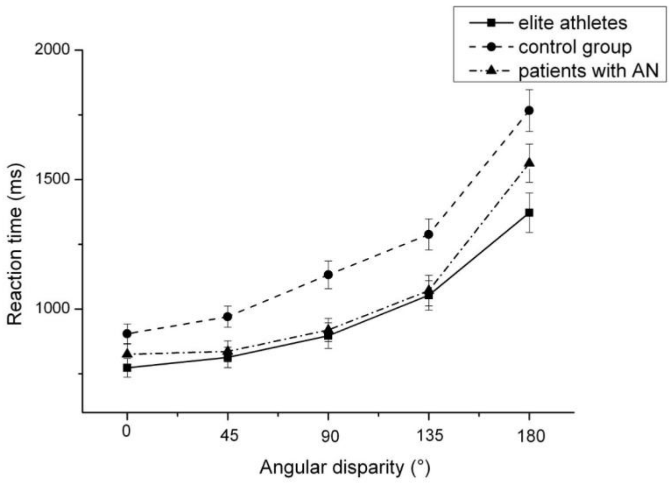

Figure 2: Mean reaction times and standard deviations (error bars) dependent on group and angular disparity.

The "angular disparity*stimulus type"-interaction was due to the fact that there was a significant difference between the reaction time of the following and previous angular disparity in both object-based conditions (BFO, letters; all $p < .001$), whereas in the egocentric transformation the only significant difference emerged between the angular disparity of 135° and 180°, $t(55) = -9.060$, $p < .001$. Because this result is not in the main focus of the study it will not be investigated further.

Mental rotation: Accuracy

The analysis of variance showed a main effect for the factor "angular disparity", $F(4,212) = 29.53$, $p < .001$, $\eta_p^2 = .358$, and a significant interaction between the factors "angular disparity" and "stimulus type", $F(8,424) = 2.92$, $p = .003$, $\eta_p^2 = .052$. There were no other significant main effects or interactions. The interaction between "angular disparity" and "stimulus type" was due to the fact that the decrease of accuracy between 0° and 180° was significantly stronger in the letter-condition (M_{Diff}=13.39%, *SD*= 18.59) compared to the BFO-condition (M_{Diff}=5.15%, *SD*= 13.07), $t(55)=.740$, $p=.463$, and the BFE-condition (M_{Diff}=6.91%, *SD*= 12.81), $t(55)=.740$, $p=.463$, whereas between the human figure conditions there was no significant difference regarding this specific response pattern, $t(55)=.740$, $p=.463$. Because this interaction was not in our main focus, it will not be analyzed further.

Further analysis showed that the overall mean reaction time was not correlated with the overall accuracy rate ($r=-.109$, $p = .424$), but with BMI ($r=.266$, $p<.05$) and IQ ($r=-.331$, $p<.01$). A stepwise regression analysis showed that IQ and BMI explained 17.7% of the variance in the mean reaction time ($R = .421$), $F(2, 53)=5.71$, $p= .006$), see Table 2.

Table 2: Final stepwise multiple regression model for the mental rotation performance in the mean reaction time based on the following predictors: group, BMI and IQ.

Predictor	Regression coefficient	ß	T	*p*
Group		.135	.902	< .05
IQ	-5.191	.327	2.623	< .05
BMI	19.205	.260	2.089	< .05

Discussion

Mental rotation performance in elite athletes and patients with Anorexia Nervosa

The results of this study show that young adults with high body awareness show a better mental rotation performance than a group of healthy controls. Whereas the accuracy did not vary between the different groups, the reaction time was faster for the elite athletes as well as for the patients with Anorexia Nervosa than for the controls. This result was independent of the kind of stimuli and that means also independent of the kind of transformation. This result does not confirm our third hypothesis. It depended on the angular disparity in that for a specific angular disparity, either the athletes or the patients or both differed from the control group. Due to these results and regarding the hypotheses we can assume that higher body awareness results in an improvement of visual spatial ability. It did not seem to play a role if this body awareness is positive like the one of the elite athletes or negative like the one of the patients with Anorexia Nervosa. Another explanation might be that not body awareness but ambition is the key factor. Because it is well known that both elite athletes and patients with Anorexia Nervosa show a higher ambition than healthy control women, this factor should be controlled in other studies. Our results further suggest that the IQ plays an important role, which could be expected because mental rotation is one part of intelligence, namely visual spatial intelligence. What is interesting is that a lower BMI was related to a better mental rotation performance, which is in line with a study of Jansen, Schmelter, Kasten and Heil (2011). This is also in accordance with another study where lower visual-spatial scores in overweight children were found (Li, Dai, Jackson, & Zhang, 2008). Children with overweight showed an impaired mental rotation performance compared to normal weight children.

One reason for the relation between body weight and cognitive performance might be that young adults with a lower BMI have a higher sensitivity for physical activity and that this higher physical activity leads to a better motor performance. This better motor performance then relates to a higher cognitive performance (see for example Pietsch & Jansen, 2012). In other words a decreased motor ability relates to an impaired visual spatial intelligence (Jansen et al., 2011). But the relation between body weight and motor ability is only one possible mediator. Another one might be that the weight relates to body esteem and that this body esteem influences cognitive processes. A third explanation might be the socio-economic status. Because it is well known that in the development of overweight the socio-economic status plays an important role (compare Jansen et al., 2011) this variable might have mediated this results. We could not exclude this assumption because socio-economic status was not investigated, but even if it was controlled as in our former study (Jansen et al., 2011), the relation between body weight and visual-spatial intelligence was visible.

In further studies concerning the investigation of mental rotation performance in young adults with higher body awareness other variables have to be controlled: motor ability, socio-economic status, body- as well as self-esteem. With the control of these variables a comprehensive picture of the integration of body, social and cognitive processes could be ventured.

The role of body awareness in the educational context

The study has emphasized the role of body awareness on a specific kind of intelligence, namely mental rotation performance. What is the importance for the educational setting? Mental rotation is one key component of intelligence, which is important for different domains: Mental rotations plays an important role in problem solving (Geary, Saults, Liu, & Hoard, 2000), and science (Peters, Chisholm, & Laeng, 1995). The ability to mentally rotate objects is also an ability needed in creative jobs, engineering, and in medical professions (Hegarty & Waller, 2005). Furthermore, in one study of Dror, Kosslyn, and Waag (1993) it was shown that pilots are better at processing mental rotation tasks than non-pilots. Mental rotation is also a relevant factor in mathematical learning (Hegarty & Kozhevnikov, 1999). Linn and Petersen (1986) showed that mental rotation is related to math ability in college students. Reukala (2001) showed that the performances in a visual-spatial memory and a mental rotation task are related to mathematical test score. All these studies show the importance of mental rotation ability for the school setting as well as the professional world. The study here gives a hint that also body processes and even such simple processes as the body weight relate to something which is relevant for the school context. It seems reasonable to assume that the body weight is not only relevant for emotional factors like self-esteem, but also for cognitive ones.

Although this study is surely limited by several points, it gives a hint that cognitive processes could not be isolated from other human body and soul. Mind, soul and body are integrated parts of each individual. To investigate one part in isolation is sometimes necessary for conducting controlled experiments.

But this study shows that the conclusions that can be drawn are limited. In practice every human being has to be seen individually, but in his or her wholeness. This is a high demand for every school- and educational setting, but is necessary for every system which wants to educate young people for a human world.

Conclusion

To conclude, this study gives support to the assumption that body awareness plays a role in cognitive processes. Further studies are needed to investigate this relation in more detail and make it useful for school context. Regarding future research directions it would be interesting to find out if this relation contributes to other cognitive tasks as well as emotional parameters.

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