# Beyond body image: what body schema and motor imagery can tell us about the way patients with Anorexia Nervosa experience their body

**Running title: Body schema and motor imagery in AN**


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# Abstract

*Aim* Recent evidence suggests that the body image disturbance often observed in patients with anorexia nervosa also extends to the body schema.  According to the embodiment approach, the body schema is not only involved in motor execution, but also in tasks that only require a mental simulation of a movement such as motor imagery, mental rotation of bodies, and visuospatial perspective-taking. The aim of the present study was to assess the ability of patients with anorexia in mentally simulate movements.

*Methods* The sample included 52 patients with acute anorexia and 62 healthy controls. All participants completed three tests of explicit motor imagery, a mental rotation test and a test of visuospatial perspective-taking.

*Results* Patients with anorexia nervosa, with respect to controls, reported greater difficulties in imagining movements according to a first-person perspective, lower accuracy in motor imagery, selective impairment in the mental rotation of human figures, and reduced ability in assuming a different egocentric visuospatial perspective.

*Conclusion* These results are indicative of a specific alteration in motor imagery in patients with anorexia nervosa. Interestingly, patients' difficulties appear to be limited to those tasks which specifically rely on the body schema, while patients and controls performed similarly in the 3D objects mental rotation task.



**Keywords**: Anorexia Nervosa, Body Image, Body Schema, Eating Disorders, Motor Imagery

## INTRODUCTION

Anorexia Nervosa (AN) is a severe mental disorder, characterized by significant restriction of food intake, leading to abnormally low body weight, intense fear of gaining weight, and high mortality rates. One of the key symptoms of AN is a disturbance in body representation, characterized by the tendency of patients to overestimate the size of their body and to report high levels of body dissatisfaction, which usually persists also following clinical remission and represents one of the main relapse factors of the disease as defined in the DSM-5 [1–3]. In recent years, it has been suggested that this alteration in body representation is not limited to the body image, but it also extends to the body schema, which is an implicit sensorimotor representation of the body in the space, involved in motor preparation and execution [4]. This hypothesis is also supported by the evidence that in healthy controls the body schema appears to be influenced by both the perceptual and attitudinal components of body image [5]. However, despite the presence of a large body of literature demonstrating that the alteration in the body schema can affect overt motor and spatial navigation abilities in patients with AN [6–9], its influence on cognitive tasks that require a mental simulation of a movement has not been explored yet.

Investigating the mechanisms subtending mental representation of movements in Anorexia Nervosa is interesting for different reasons. Firstly, motor imagery is thought to rely on mechanisms and mental representations similar to those involved in action execution, including the body schema [10,11]. Moreover, according to recent neuroscientific findings, motor imagery and action execution activate a partially overlapping frontoparietal neural circuit, which has already been shown to be both structural and functionally involved in the neurobiology of AN [12–14]. Lastly, the ability to mentally represent body movements is likely to have multi-level implications, ranging from the experience that a subject has of his/her own body, to the ability to take both spatial and interpersonal perspectives [15].

To date, different tasks have been proposed to evaluate the ability to mentally simulate a body movement. Among these are included tasks in which participants are explicitly asked to imagine performing an action, in particular in conditions requiring the adoption of an egocentric/kinesthetic perspective. Kinesthetic motor imagery involves the recreation of the muscular and physical sensation of performing an action and is considered to be more embodied than visual motor imagery [16]. However, there exists also tasks that are performed through an implicit body movement simulation, such as mental rotation of bodies/body parts and level-2 visuospatial perspective-taking (VPT) [17]. In more detail, in mental rotation tasks, participants are required to compare stimuli presented at different degrees of rotation and to judge whether they represent the same object seen from a different perspective or not. While the mental rotation of 3D objects relies on a visuospatial strategy centered on the object, bodies and body parts seem to promote a motor simulation centered on the body, which usually facilitates performance [18,19]. Consistent with this approach, evidence of selective impairment in the mental rotation of body parts have been observed in patients with different movement disorders, such as Parkinson's disease, myotonic dystrophy, and dystonia [20–22].

Level-2 VPT consists in adopting a different point of view to understand how the world is represented from that perspective [23]. The fact that the performance is influenced by participant's body posture and by the angular disparity between the egocentric and the target perspective, highlights the embodied nature of level-2 VPT and supports the view that to perform these tasks, participants mentally simulate a rotation of the body into the target location [17,24].

At present, the ability of AN patients to perform this type of task has been poorly investigated. Two studies adopted a laterality judgment task to assess the ability of AN patients to mentally rotate human figures, but they obtained opposite results [25,26]. While Cipolletta and colleagues (2017) observed a reduced performance in AN patients, Kaltner and colleagues (2015) reported greater mental rotation abilities in patients than in HC, independently from stimulus type (human figures or letters). Using a similar laterality judgment task with hand stimuli, Campione and colleagues (2017) observed that HC were faster in rotating a picture of their own hand compared to someone else's hand, while patients with eating disorders did not show this advantage. However, the two groups did not differ in their ability to mentally rotate unfamiliar hand stimuli [27].

Lastly, Lander and colleagues [28] assessed patients' ability in level-2 VPT using the object-perspective taking test [29] and they observed a lower performance in patients with AN than in HC. However, the sample included only 20 patients with AN and 35 HC, and replication with a larger sample size may thus help validate and generalize their findings.

The present study aimed to assess the ability of patients with AN in the mental simulation of movements by means of different tasks. Explicit motor imagery abilities, which have never been investigated in AN, were assessed through two objective tests, the Test of Ability in Movement Imagery [30] and the Mental Chronometry test [31], and one self-reported-questionnaire, the Vividness of Movement Imagery Questionnaire-2 [32]. Patients' abilities in mental rotation were assessed with a test including both 3D objects and human figures [33]. Finally, level 2 VPT was investigated with the Object-Perspective Taking Test [29].

Since patients with AN are likely to experience an altered body schema, we hypothesized that this alteration also affected their performance on tasks that require a mental simulation of a movement. Therefore, we expected to observe in this group:1) greater difficulties than HC in performing tasks of motor imagery, in particular in conditions requiring participants to adopt an egocentric/kinesthetic perspective; 2) selective impairment in the mental rotation of human figures, which involves the mental simulation of a movement centered on the body; 3) preserved performance in the mental rotation of 3D objects, which relies on an object-based rather than on an embodied transformation; and 4) greater difficulties than HC in level-2 VPT, as already observed by Lander and colleagues (2020). Moreover, we wanted to assess the association between the performance obtained on the body schema related cognitive tasks and several clinical variables, such as illness duration, age of onset, anxiety, and eating disorder severity.

## METHODS

**Participants**

The sample included 52 patients with acute AN (age range: 14-31 years) and 62 healthy controls (HC, age range: 14-32 years), all females.

Patients were recruited from the Eating Disorder Unit of the University Hospital of Padova and from the Eating Disorder Unit of the San Bortolo Hospital, Vicenza. All patients met full criteria for AN, according to the DSM-5 [2], and they were all enrolled in a semi-hospitalization program. Exclusion criteria for both patients and HC were: 1) male gender; 2) age under 14 years; 3) current or lifetime neurological diseases; 4) mental impairment or learning disabilities; 5) bipolar disorder or schizophrenia spectrum disorder, and 6) history of drug/alcohol dependence. An additional exclusion criterion for healthy controls was the presence of a current or lifetime diagnosis of an eating disorder or other psychiatric disorders.

Written informed consent was provided by all participants. In the case of underage participants, consent was provided by their parents or legal guardian. The study was approved by local ethical committees and was conducted in accordance with the latest version of the Declaration of Helsinki.

**Procedure**

At the beginning of the test session, an expert clinician evaluated the presence of AN diagnosis using a diagnostic interview according to the Eating Disorders Section of the Structured Clinical Interview of the DSM-5 [2]. All participants than provided a series of demographic and clinical information (age, years of education, body mass index (BMI), current pharmacological treatments), and they completed the State-Trait Anxiety Inventory (STAI) for the assessment of trait and state anxiety [34]. Patients also filled in the Eating Disorder Inventory (EDI), which is a self-administered questionnaire for the assessment of eating disorder psychopathology [35]. The scale comprises 64 items, divided into 8 subscales. Of the 8 subscales, we took into consideration the three scales more related to body representation: interoceptive awareness, body dissatisfaction, and drive for thinness. Data related to the duration of the disease (in months), age of onset, and lower weight ever reached were collected by the experimenter by looking at patients' medical records. Hand lateralization was assessed through the Edinburgh Handedness Inventory [36], which yields scores ranging from –100, denoting consistent left- handedness, to +100, denoting consistent right-handedness. Lastly, to exclude mental impairment, and to obtain an estimate of participants' verbal IQ, all participants over the age of 20 completed the Brief Intelligence Test (Test Breve di Intelligenza, TIB) [37], while participants younger than 21 completed the Information subtest of the Wechsler Intelligence Scale (the children version if participants were aged 16 or less, and the adult version if their age was between 17 and 20 years) [38,39].

Participants then performed the following body schema related cognitive tests and questionnaire: 1) Test of ability in movement imagery (TAMI); 2) Mental Rotation Test (MRT) with 3D objects and human figures; 3) Perspective Taking/ Spatial Orientation Test; 4) Mental Chronometry Test, and 5) Vividness of Movement Imagery Questionnaire (VMIQ2). The order of test presentation was randomized between subjects. All the cognitive measures included in the battery are presented and further explained in the following section.

**Body Schema related Cognitive Measures**

*Test of Ability in Movement Imagery (TAMI)*

The TAMI is an objective test for the assessment of motor imagery abilities, developed by Madan and Singhal (2013). The test is composed of 1 practice question and 10 test questions. Each question begins with the instruction of imagining being in an upright position ("Stand up straight with your feet together and your hands at your sides"). Participants are then provided with a description of a sequence of movements, and they are asked to imagine the given set of movements without performing them in real life. Subsequently, participants are presented with 5 different images, and their task is to select the image that corresponds to their final body positioning. The options "none of the above" and "unclear" are also present in all trials. The correct response for each question is weighted from 1 to 5 points, according to its difficulty [40]. Total TAMI scores range from 0 to 24 points.

*Mental Rotation Test (MRT) with 3D objects and human figures*

In this study, we adopted the modified version of the original MRT [41,42], developed by Alexander and Evardone [33]. The modified procedure task is composed of 4 practice trials and 23 test trials, 11 with 3D block configurations and 12 with human figures (six males and six females, wearing identical clothing). In each trial, the participant is presented with a reference picture (the target) and four "response" pictures, two of which display the same item represented in the target picture, but rotated, while the other two display a different item.

For each question, the answer is scored as correct only if the participant identifies both the correct response pictures. The proportion of correct responses and mean response time (in seconds) for both the 3D objects and the human figures conditions were recorded. To take into account both accuracy and execution speed simultaneously, the proportion of errors and mean response time were z-standardized to be in the same metric and then they were averaged into an overall performance index, with higher z scores indicating a worse performance.

*Perspective Taking/ Spatial Orientation Test*

In this study, we adopted the revised version of the Perspective Taking/Spatial Orientation Test, developed by Hegarty and Waller (2004). The task comprises 1 practice trial and 12 test trials. In each trial, participants are presented with a map depicting 7 objects, and they are asked to imagine being at the location of one of the objects (station point), facing another object (facing object). Their task is to indicate the position of a third object, by drawing an arrow in a circle in which the station point is drawn in the center and the facing object is drawn as an arrow pointing vertically up. Mean deviation (in degrees) from the correct response and total time (in minutes) required to complete the task were recorded. As for the MRT, the two dependent variables were z-standardized and then averaged to obtain a single performance index, which considered both accuracy and response times conjointly. Even in this case, higher scores were indicative of a lower performance.

*Mental Chronometry Test*

The mental chronometry test utilized in this study is an adaptation from Williams et al. [31]. The test includes 4 blocks. In each block, participants read the description of a movement taken from the Movement Imagery Questionnaire-3 [43]. Participants are then asked to both actually perform the described action and imagine the movement using three different perspectives: external visual imagery (EV, imagining oneself performing an action from a third-person perspective), internal visual imagery (IV, imagining oneself performing an action from a first-person perspective), and kinesthetic imagery (K, imagining the physical and muscular sensation of performing the action). Half of the participants start each block by performing the action, while half of the participants start by imagining the movement and then performing the action. The experimenter records the time needed to actually perform the action, while the participant himself records the time needed to imagine the movement according to each perspective. For each movement and each perspective, a discrepancy score is calculated by subtracting the "imaging" time from the "physical execution" time. The absolute discrepancy scores are then used to calculate an average discrepancy score for each perspective.

*Vividness of Movement Imagery Questionnaire (VMIQ2)*

The VMIQ2 is a subjective questionnaire for the assessment of motor imagery [32]. Participants are provided with a list of 12 common movements (e.g., "running", "cycling") and they are asked to imagine performing each movement according to three different perspectives: external visual imagery (EV), internal visual imagery (IV), and kinesthetic imagery (K). For each movement and imagery type, participants rate the vividness of the imagined movement on a 5-point Likert scale, where a rating of 1 corresponds to the clearest and most vivid image. For each subscale (EV, IV, and KI) the score ranges from 12 to 60.

### Statistical Analyses

Since most of the variables under investigation did not follow a normal distribution, we decided to conduct non-parametric analyses. Differences between groups in both demographic and cognitive measures were tested using the non-parametric Mann-Whitney U test. As an exploratory analysis, we also decided to assess differences in cognitive measures between groups separately for adolescents (14-17 years) and adults (over 18 years).

For those tests which included different within-subjects conditions (MRT, Mental Chronometry Test, and VMIQ2), a repeated measure non-parametric Aligned Rank Transform (ART) ANOVA was conducted to test the main effects and the significance of the group by condition interaction [44].

Relationships between clinical data (BMI, age of onset, illness duration, lower body weight, STAI state, STAI trait, EDI body dissatisfaction, EDI interoceptive awareness, EDI drive for thinness, estimated verbal IQ, and handedness) and all the body schema related cognitive measures and between the different cognitive measures themselves were tested by means of the Spearman Rho correlation, separately for controls and patients. In order to correct correlations for multiple comparisons, False Discovery Rate (FDR) was used, and only p-values equal to or lower than 0.008 were considered significant.

All statistical analyses were conducted using the software SPSS, version 26 (IBM, 2019).

## RESULTS

### Demographic characteristics

Table 1 summarizes the demographic and clinical characteristics of both patients with AN and healthy controls. As expected, patients with AN presented a lower BMI and higher levels of both state and trait anxiety compared to HC. Moreover, HC presented significantly higher scores at the Edinburgh Handedness Inventory, indicating greater right-handedness than patients with AN, and greater estimated IQ. Concerning current pharmacological treatment, none of the HC participants was taking psychotropic medications, 23 patients were under antidepressant drugs, 4 were taking benzodiazepines, and 20 were taking antipsychotics drugs (olanzapine or risperidone).

**Body-Schema related Cognitive Measures**

*Between-subjects analyses*

Table 2 reports the mean accuracy scores and response times of both patients with AN and HC in the cognitive tests and questionnaires. Patients with AN displayed lower accuracy than HC in the Test of Ability in Movement Imagery, in the MRT of human figures, and in the Spatial Orientation Test. The results for the MRT and Spatial Orientation Test were also confirmed by the analyses conducted on z scores, which considered accuracy and response times conjointly. Patients also reported significantly lower vividness of imagined movement according to the internal visual and kinesthetic imagery perspectives, compared to HC. Since patients with AN and HC differed in their hand lateralization, we conducted the same analyses excluding left-handed participants. The previously observed differences remained significant and therefore are not further reported.

In the supplementary materials are reported the mean accuracy scores and reaction times of patients and HC divided by developmental stage: adolescents (table S1), and adults (table S2).

*Within-subjects analyses*

The repeated measure non-parametric ANOVA conducted on MRT accuracy scores revealed a significant main effect of group ($F(1,112) = 4.91$, $p = .029$) and a significant main effect of condition ($F(1,112) = 93.51$, $p < .001$). However, the interaction group by condition was not statistically significant ($F(1,112) = 0.01$, $p = .956$).

The repeated-measure analysis conducted on MRT response times revealed a significant main effect of condition (F (1, 112) =47.03, $p>.001$), and a significant condition by group interaction (F (1, 112) =5.22, p=.024). In particular, as depicted in figure 1a, both patients and HC were faster in responding to human figures than to 3D objects, however, HC presented an higher benefit in response time compared to patients. No significant main effect of group emerged (F (1, 112) =1.37, p=.244).

As regards the mental chronometry task, we did not observe any significant result: main effect of group (F (2,218) =0.31, p=.582), main effect of condition (F (2,218) =0.20, p=.820), group by condition interaction (F (2,218) =1.32, p=.271).

With respect to the VMIQ2 questionnaire, the analyses revealed a significant main effect of condition (F (2, 220) = 9.658, $p<.001$), a significant group by condition interaction (F (2, 220) = 4.75, p=.010), and a trend toward a main effect of group (F (2, 220) = 3.37, p=.069). As shown in graph 1b, both AN patients and HC reported lower vividness (higher scores) of movements imagined according to the external visual perspective, as compared to other perspectives. However, HC reported a greater increase in vividness when moving to the internal and kinesthetic perspectives, compared to patients with AN.

**Correlations between cognitive measures and clinical variables**

The correlations between all the cognitive measures and the following clinical variables were assessed: BMI, age of onset, illness duration, lower body weight, STAI state, STAI trait, EDI body dissatisfaction, EDI interoceptive awareness, EDI drive for thinness, IQ, and handedness.

No significant correlations were observed between clinical variables and body-schema related cognitive measures in the AN patients' group. In the HC group, instead, we observed a positive correlation between state anxiety and the score obtained at the kinesthetic scale of the VMIQ2 ($\rho$=.350, *p*=.005).

Correlations between different cognitive measures in both AN patients and HC are reported in Table 3.

**DISCUSSION**

In the present study, we evaluated motor imagination abilities in a sample of patients with AN and HC by means of three tests of explicit motor imagery, and two tasks that implicitly require a mental simulation of a body movement: the mental rotation of human figures, and level-2 visuospatial perspective-taking. The presence of positive associations between the performance obtained in different tasks, together with the observation that correlations were stronger within the same task, suggest the involvement of a common underlying mechanism, but also indicate the uniqueness of each task in explaining participants' behavior.

Our results evidenced that patients with AN displayed greater difficulty than HC in explicitly imagining movements, as measured by the TAMI and the VMIQ tests, in mentally rotating human figures, and in adopting a different egocentric visuospatial perspective. No significant differences between patients and HC were detected in the Mental Chronometry Test and in the mental rotation of 3D objects.

Collectively, these findings are in line with the hypothesis of an alteration in the ability to mentally represent movements in AN. Moreover, our findings suggest that these motor imagery alterations are embedded in the body schema. This assumption primarily originates when assessing subjective motor imagery. Indeed, when patients were asked to imagine movements according to an internal or kinesthetic perspective, they reported lower vividness compared to HC, while no between-group differences were observed when using the external visual perspective. Interestingly, according to Lorey and colleagues [16], only first-person motor imagery involves the generation of an internal motor plan grounded on the body schema, while external motor imagery relies on a more visual and abstract representation of movements. The fact that the use of a first-person perspective facilitates performance only in HC, may indicate that patients with AN have difficulties in utilizing their body schema to solve this type of cognitive tasks and that they might tend to represent movements in a visual, rather than in a kinesthetic and motoric way.

The fact that the difficulties observed in patients with AN are related to the body schema is also supported by the evidence that the two groups did not differ in their ability to mentally rotate 3D objects, but they differ in their ability to rotate human figures. It has been shown that only the use of body/body parts in mental rotation tasks promotes an implicit motor simulation which usually facilitates performance [18]. Although both patients and HC displayed an advantage for body figures compared to 3D objects, in HC this facilitation effect was significantly greater than in patients with AN. As far as we know, this is the first study to highlight a dissociation between the ability to mentally rotate human figures and 3D objects in a sample of patients with AN. Moreover, our results are in line with those of some previous studies showing no differences between patients and HC in the ability to mentally rotate geometric objects [28] and a reduced ability of patients with AN in the mental rotation of human figures [26]. Similar results were also obtained in a sample of patients with bulimia nervosa, while no impairment in the mental transformation of bodies was observed in patients with BED, suggesting a possible link between cognitive performance and body image disturbances [45]. Moreover, the selective impairment in the mental rotation of human figures further supports the hypothesis that patients with AN may have difficulties in tasks that specifically rely on their body schema. Indeed, while the mental rotation of human figures seems to entail the use of one’s own body as a key reference to overcome mental imagery task, mental rotation of 3D objects relies on external visual representation and transformation [46].

The difference between the mental rotation of abstract objects and the mental rotation of human figures has been previously observed also at the neurobiological level. A meta-analysis conducted on neuroimaging studies, indeed, observed that motor regions in the precentral cortex were more often activated during the mental rotation of hand stimuli, rather than three-dimensional objects[47]. Moreover, Jansen and colleagues [48], in a recent event-related potential study conducted on healthy subjects, observed that embodied stimuli elicited a different pattern of activation, compared to abstract (cube) figures, in the parietal and central areas of the brain in the earlier time interval (200-400 ms), and in the frontal and central brain regions during the later time interval (400–600 ms). Given the alterations observed at the behavioral level, future studies should evaluate whether human stimuli elicit, in patients with AN, an abnormal pattern of activation also at the neural level. This evidence would be interesting also in light of previous observations highlighting the possible involvement of the parietal lobe in the impairments of visuospatial abilities in patients with AN [49].

In order to expand our observations to other cognitive functions that have been previously associated with visuospatial abilities and that rely on parietal lobe activity and body schema, we explored whether patients with AN showed an impairment in level 2 visuospatial perspective taking abilities. Consistent with our hypothesis, patients with AN displayed more difficulties than HC-in assuming a different visuospatial perspective. This evidence replicates, with larger sample size, the results obtained by Lander and colleagues (2020), and further highlights the difficulty of patients with AN in performing tasks that require an egocentric mental transformation of the body.

Lastly, we assessed explicit motor imagery abilities in patients with AN using the TAMI, a task that was specifically designed to assess the ability of imagining body movements [30]. In our study, the mean scores obtained by the HC group were similar to the one observed by Madan and Singhal [50] in a sample of 123 healthy young women. However, as hypothesized, patients with AN presented a lower accuracy than HC in explicitly imagining movements, suggesting that patients with AN have an impaired ability to mentally simulate body movements.

The results obtained dividing the sample into adolescents and adults suggest that the impairments in motor imagery observed in patients with AN may vary according to their developmental stage. However, since the new samples were quite small, this aspect should be further investigated in future studies employing larger sample size.

From a clinical perspective, the difficulties shown by patients with AN in this study may have implications also for their social and interpersonal functioning. According to the embodied perspective, indeed, mental simulation of movements is involved in the observation and comprehension of other people's actions [10], and visuospatial perspective-taking forms the basis of the psychological and empathic forms of perspective-taking [15]. The development of intervention targeting body image and body schema disturbances in AN could therefore have a broad impact on patients' psychological functioning, ranging from enhanced self-esteem to increased interpersonal abilities.

The present study has some limitations that need to be considered. Firstly, it is a cross-sectional study that only includes patients in the acute phase of AN, and this prevented us from assessing the effects of weight recovery on the evaluated cognitive functions [51]. Secondly, we only recruited female participants and thus our results cannot be generalized to the male population.

Despite these limitations, this study has the strength of having demonstrated, for the first time and with the largest sample size studied so far, the presence of an alteration in movement imagery in patients with AN. This alteration is not limited to explicit motor imagery, but it also extends to tasks that implicitly elicit an egocentric mental transformation of the body, indicating also a possible association between body image disturbances, motor imagery, and social cognition impairments in patients with AN. Given the importance of the body and its related alterations in perception, cognition, and emotions and considering the poor response to treatment observed in patients with AN, it is crucial to identify those factors that may contribute to the maintenance of the disease in order to disentangle the complexity of the disorder and identify more effective interventions.

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**DISCLOSURE STATEMENT**

The authors declare no conflict of interest

## AUTHOR CONTRIBUTIONS

VM and EC were involved in the conception and design of the study; VM, ET, ES, PM, EC, SZ, and AS contributed to patients' recruitment and data acquisition, VM, EC, and CRM were involved in the analysis of data; VM contributed to drafting the manuscript, AF, ET, CRM, and EC revised the manuscript

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**Table 1.** Differences in demographic and clinical data between patients with AN and HC

| | **AN (n=52) Mean (SD)** | **HC (n=62) Mean (SD)** | **U (*p*)** |
|---|---|---|---|
| Age (years) | 19.10 (4.21) | 20.45 (5.37) | 1464 (.398) |
| Education (years) | 12.04 (2.65) | 13.60 (3.82) | 1287 (.062) |
| BMI (kg/cm$^2$) | 15.87 (1.31) | 20.78 (1.92) | **23 (<.001)** |
| Age of onset (years) | 16.79 (3.20) | - | - |
| Illness duration (months) | 33.83 (38.02) | - | - |
| Lower Weight | 40.20 (4.62) | - | - |
| EDI int. awareness | 12.69 (9.16) | - | - |
| EDI body dissatisfaction | 16.20 (10.32) | - | - |
| EDI drive for thinness | 12.78 (8.88) | - | - |
| Estimated IQ | 103.49 (11.06) | 108.81 (6.95) | **580 (.003)** |
| Handedness | 56.21 (30.21) | 68.01 (23.95) | **1168 (.025)** |
| State Anxiety (STAI) | 50.27 (12.56) | 37.47 (11.64) | **658 (<.001)** |
| Trait Anxiety (STAI) | 59.25 (11.07) | 42.42 (10.86 | **422 (<.001)** |

AN, Anorexia Nervosa; HC, healthy control; STAI, State-Trait Anxiety Inventory

**Table 2.** Differences between patients with AN and HC in all the cognitive variables

| | AN (n=52)<br>Mean (SD) | HC (n=62)<br>Mean (SD) | U (*p*) |
|---|---|---|---|
| TAMI | 14.42 (4.87) | 16.45 (4.11) | **1237 (.032)** |
| MRT 3D objects (accuracy) | 0.46 (0.26) | 0.54 (0.25) | 1302 (.076) |
| MRT human (accuracy) | 0.64 (0.30) | 0.77 (0.21) | **1244 (.035)** |
| MRT 3D objects (time) | 25.88 (15.61) | 29.08 (12.19) | 969 (.092) |
| MRT human (time) | 22.58 (14.10) | 21.95 (9.78) | 1186 (.872) |
| MRT objects (z) | 0.11 (0.72) | 0.00 (0.63) | 1501 (.528) |
| MRT human (z) | 0.38 (0.97) | 0.00 (0.79) | **1206 (.021)** |
| Spatial Orientation Test (diff) | 41.72 (27.97) | 28.36 (16.45) | **1194 (.018)** |
| Spatial Orientation Test (time) | 5.08 (1.85) | 4.55 (1.90) | 1338 (.120) |
| Spatial Orientation Test (z) | 0.54 (0.98) | 0.00 (0.77) | **1089 (.003)** |
| Mental Chronometry EV | 1.38 (1.32) | 1.28 (1.13) | 1392 (.431) |
| Mental Chronometry IV | 1.41 (1.48) | 1.29 (1.03) | 1512 (.939) |
| Mental Chronometry K | 1.50 (1.55) | 1.14 (0.78) | 1374 (.372) |
| VMIQ2 EV | 27.48 (11.03) | 27.27 (8.92) | 1544 (.974) |
| VMIQ2 IV | 25.86 (9.71) | 21.73 (7.78) | **1179 (.030)** |
| VMIQ2 K | 26.98 (9.12) | 22.55 (9.26) | **1073 (.005)** |

AN, Anorexia Nervosa; HC, healthy controls; TAMI, Test of Ability in Movement Imagery; MRT, Mental Rotation Test; VMIQ2, Vividness of Movement Imagery Questionnaire; EV, external visual imagery; IV, internal visual imagery; K, kinesthetic imagery.

**Table 3**. Correlations between different cognitive measures in the HC group and in the AN patients group

| | TAMI | MRT obj | MRT hum | S. O. | M. C. EV | M. C. IV | M. C. K | VMIQ2 EV | VMIQ2 IV |
|---|---|---|---|---|---|---|---|---|---|
| ***HC group*** | | | | | | | | | |
| TAMI | 1.00 | | | | | | | | |
| MRT 3D obj (z) | -.246 | 1.00 | | | | | | | |
| MRT human (z) | -.203 | **.449*** | 1.00 | | | | | | |
| S. Orientation (z) | -.148 | **.445*** | **.563*** | 1.00 | | | | | |
| M Chronometry EV | .001 | .035 | .107 | .062 | 1.00 | | | | |
| M Chronometry IV | -.005 | .121 | .278 | .231 | **.823*** | 1.00 | | | |
| M Chronometry K | .057 | .176 | .208 | .116 | **.805*** | **.821*** | 1.00 | | |
| VMIQ2 EV | -.324 | .055 | **.337*** | .095 | .090 | .128 | -.029 | 1.00 | |
| VMIQ2 IV | **-.353*** | .085 | .204 | .126 | .130 | .144 | .126 | **.477*** | 1.00 |
| VMIQ2 K | -.172 | -.043 | .128 | .156 | .005 | -.002 | .024 | .314 | **.741*** |
| ***AN group*** | | | | | | | | | |
| TAMI | 1.00 | | | | | | | | |
| MRT 3D obj (z) | .042 | 1.00 | | | | | | | |
| MRT human (z) | -.170 | **.532*** | 1.00 | | | | | | |
| S. Orientation (z) | -.282 | **.410*** | **.382*** | 1.00 | | | | | |
| M Chronometry EV | -.240 | -.008 | .148 | .040 | 1.00 | | | | |
| M Chronometry IV | -.283 | .100 | .332 | .005 | **.778*** | 1.00 | | | |
| M Chronometry K | -.254 | .116 | .275 | .020 | **.861*** | **.848*** | 1.00 | | |
| VMIQ2 EV | .053 | .109 | .071 | .088 | .060 | .051 | .089 | 1.00 | |
| VMIQ2 IV | .032 | .052 | .197 | .233 | .044 | .023 | .057 | **.640*** | 1.00 |
| VMIQ2 K | -.191 | .206 | .278 | .156 | .232 | **.405*** | .343 | **.520*** | **.405*** |

Colour scale: 1.0, 0.8, 0.6, 0.4, 0.2, 0, -0.2, -0.4, -0.6, -0.8, -1.0

AN, Anorexia Nervosa; HC, healthy controls; TAMI, Test of Ability in Movement Imagery; MRT, Mental Rotation Test; VMIQ2, Vividness of Movement Imagery Questionnaire; EV, external visual imagery; IV, internal visual imagery; K, kinesthetic imagery

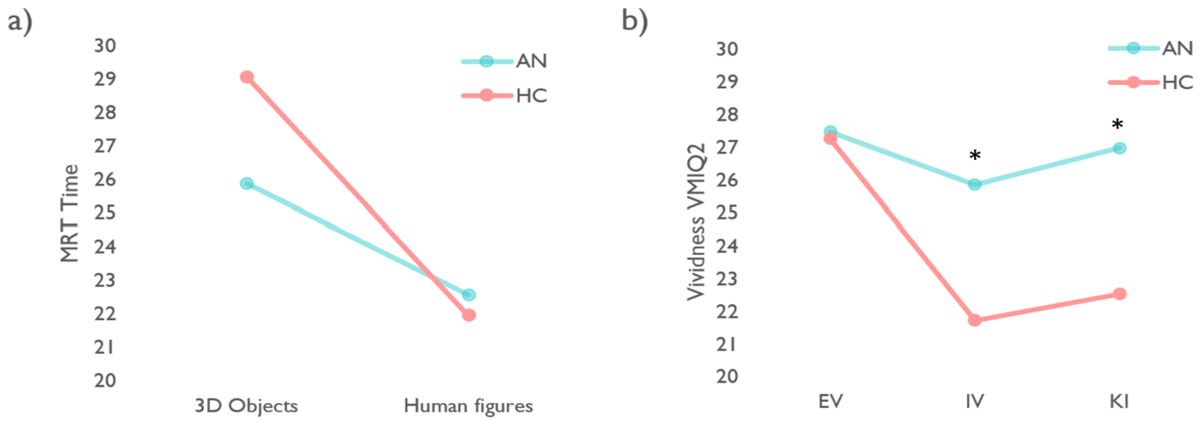


**Figure 1.** Significant group by condition interaction in the Mental Rotation test Response Time (a) and in the Vividness of Movement Imagery Questionnaire (b). Legend: AN, Anorexia Nervosa; HC, healthy controls; MRT, Mental Rotation Test; VMIQ2, Vividness of Movement Imagery Questionnaire; EV, external visual imagery: IV, internal visual imagery; KI, Kinesthetic imagery