UNIVERSITY OF PADOVA

Department of General Psychology*

Master's Degree in Cognitive Neuroscience and Clinical Neuropsychology

Final dissertation

Anorexia Nervosa: difficulties in body schema representation and motor imagery.

Supervisor
Professor Angela Favaro

Co-supervisor
PhD. Enrico Collantoni
Dott. Valentina Meregalli

Candidate: Noelia Peña Arauzo
Student ID number: 2009382

Academic Year 2021-2022

CONTENTS

ABSTRACT

Anorexia nervosa (AN) is a psychiatric disorder where the physical appearance becomes the priority of the person, which shows a strong fear of becoming fat and a distortion of the real body size. Recent investigations have shown that AN is not only a disease related to body image, spatial and motor navigation can also be impaired due to body schema alterations.

In the present study, we were focused on studying the body schema, which is the unconscious mental representation of an action. We measure it with tests that are related with the mental simulation of a movement, and we wanted to observe if this mental simulation would be altered considering the body schema of patients suffering from AN.

The sample consisted of 52 patients with AN and 62 healthy controls (HC). All participants completed two implicit motor imagery tests, the Mental Rotation with both 3D objects and human figures and the Perspective-taking/Spatial Orientation, and three explicit motor imagery tests, the Test of Ability in Movement Imagery (TAMI), the Mental Chronometry test, and the Vividness of Movement Imagery Questionnaire. It was found that patients with AN show an impairment in the ability to mentally imagine body movements, have greater difficulties in imagining the vividness of a movement when they are asked to use the kinesthetic or internal perspective, have worse accuracy in mentally rotating human figures, and displayed more difficulties than HC in assuming a different visuospatial perspective. Nevertheless, patients with AN and HC show similar results in mentally rotating 3D objects.

The obtained results indicate that patients suffering from AN show an alteration in the ability to mentally represent movements.

***Keywords*:** anorexia nervosa, motor imagery, body schema, kinesthetic.

INTRODUCTION

Anorexia Nervosa: definition, etiology, epidemiology, and comorbidity

According to the Diagnostic and Statistical Manual of Mental Disorders, DSM-V (American Psychiatric Association, 2013), anorexia nervosa (AN) is a psychiatric disorder characterized by a) the presence of significant low body weight due to the limitation of energy; b) strong fear of increasing weight or becoming fat; and c) the mental distortion of the real size of the body, without being conscious of the low body mass index (see table 1).

Table 1.

Diagnostic criteria of Anorexia Nervosa in DSM-V.

Diagnostic Criteria following the DSM-V
A. Restriction of energy intake relative to requirements, leading to significantly low body weight in the context of age, sex, developmental trajectory, and physical health. *Significantly low weight* is defined as a weight that is less than minimally normal or, for children and adolescents, less than that minimally expected.
B. Intense fear of gaining weight or of becoming fat, or persistent behaviour that interferes with weight gain, even though at a significantly low weight.
C. Disturbance in the way in which one's body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or persistent lack of recognition of the seriousness of the current low body weight.

Note. Recovered from The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, DSM-V. (2013, p.338-339).

The person that suffers from AN can be classified as restricting type, where the person doesn't present binge eating or purging behaviours during the last three months, or binge eating/purging type, where the person presents some of these behaviours during the last three months. The remission can be partial if Criterion A is not met for a continuous period (but Criteria B and/or C are still met), or full remission if all the criteria are not met during an interrupted period (APA, 2013).

The prevalence is higher in females than in males, with a 10:1 female-to-male ratio (APA, 2013), with a lifetime prevalence of up to 4% in females and up to 0.3% in males (Van Eeden, Van Hoeken, & Hoek, 2021). Certain attitudes are correlated with the development of AN, such as the practice of certain sports, like swimming, gymnastics, or dance, where weight and perfectionism are a cue in the performance (UK sport, 2007).

The age of onset of AN usually begins during adolescence or early adulthood. In a study conducted by Hindler et al. (1994), they showed that the age of onset of AN (from data collected during 1960-1990) was 18.1 years in males and 17.4 years in females, but recent investigations have shown that the age of onset is decreasing, with a peak around 16 years, and with an increasing frequency before 16 years (Favaro et al., 2009). The increased risk of developing AN in younger years could be due to the interaction of different factors, such as the early age of menarche. Moreover, AN is becoming more frequent: in the UK, it was tracked the rate of admissions for AN, and they observed that from the 1960-1990 track to the 2002-2011 track, the number of female populations suffering from AN doubled (Alvarez-Male, Bautista, & Serra, 2015, as cited in Keski-Rahkonen, & Mustelin, 2016).

The mortality rate in AN is 5,6% per decade, of which 54% are due to medical complications, 27% due to suicide, and the other 19% due to other or unknown causes (Sullivan, 1995). The weight loss, the malnutrition (which can arrive at a starvation level), and the purging behaviours are the causes of the serious health problems that affect all the human organs and systems: skin, head, ears, eyes, nose, throat, pulmonary, cardiac, gastrointestinal, hepatic, immunologic, neuromusculoskeletal, endocrine and renal (Gibson, Workman, & Mehler, 2019). All the complications can improve with proper nutrition and appropriate weight gain, except for the osteoporosis, in which it has been seen that even with medical treatment the completely recover is not possible (Anand & Mehler, 2019). In addition, acute weight loss implicates the grey and white matter brain atrophy, which can mostly return to normal levels after weight restoration, with no significant differences from healthy controls (Seitz et al., 2014).

In AN not only the medical conditions are present, if not that frequently comorbid psychiatric disorders are prominent, being the most common the anxiety disorders (such as social phobia or specific phobias), mood disorders (such as depressive disorder, social withdrawal, insomnia, low sexual interest, depressed mood, and irritability), obsessive-compulsive behaviours (related or not related with food), substance use disorders, self-injury and suicide (APA, 2013; Keski-Rahkonen & Mustelin, 2016).

The pathogenesis of AN is explained by Garner (1993) from a multifactorial perspective which includes individual, familial, and cultural predisposition (Figure 1). The individual predisposition is composed of psychological factors such as the emotional instability, depression, anxiety (being obsessions and compulsions frequent symptoms), personality disorders (avoidant and borderline personality disorder show a high prevalence), emotional and cognitive deficits (with a strong concern about the appearance, which can be reinforced by the sociocultural context), body image (which is disturbed and is one of the core symptoms of AN), the physical or psychological trauma (as sexual abuse), genetics, developmental and physical vulnerability (which includes exposure to infections, alcohol and advanced maternal age…, during the prenatal and perinatal period), and metabolic and neuroendocrine irregularities (being the most consistent the hypothalamic-pituitary-gonadal axis).

Continuing with Garner’s model, the familial predisposition is described as mothers who are intrusive, ambivalent, and dominants, and fathers who are ineffective and compliant.

Sometimes the interaction of the family is set as codependent, with excessive protection, inflexibility, and avoidance of family disputes. The cultural predisposition is the pressure that women suffer from having a beautiful, athletic, and thin body.

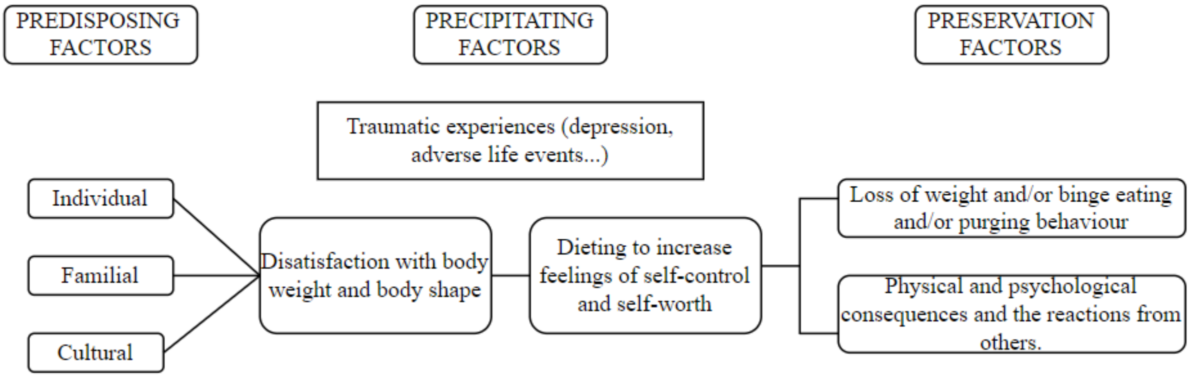

Figure 1. Pathogenesis of AN following the multifactorial model of Garner. Adapted from "Pathogenesis of anorexia nervosa" (pag. 4), by Garner, 1993, *The Lancet, 341(8861).*

Concerning the recovery time of AN, a recent study conducted by Eddy et all. (2021) show that during the 22-year follow-up of 222 women suffering from AN or bulimia nervosa, at the 9-year follow up only one-third of the women suffering from AN were recovered in comparison with the two-thirds of the women suffering from bulimia nervosa. At the end of the 22-year follow-up, 62.8% of the patients suffering from AN were recovered.

Body schema and body image in Anorexia Nervosa

After a brief introduction on AN, it is important to clarify some concepts, such as what is body image, body schema and motor imagery.

Body image could be described as how we perceive our physical appearance, which includes our beliefs, emotions, bodily sensations, and other cognitions that are experienced regarding our own body (Kostecka, Kordynska, Katarzyna, Murawiec, & Kucharska, 2019). The distortion of the body image is one of the risk factors for developing AN, one of its main symptoms, a diagnosis and a maintenance factor, and a predictor of its possible relapse in AN (Magrini et al, 2022). It can be thought of as a multidimensional construct, assuming both top-down (i.e., memory, beliefs, mood states and attitudes concerning the physical appearance) and bottom-up aspects (proprioceptive and visual information) (Demartini et al., 2020).

Body image disruption depends on some aspects, such as *body image dissatisfaction*, and *perceptual distortion*. On one hand, body image satisfaction depends on the inter-and intrapersonal experiences that a person has with his/her own body, and it is determined by the difference between the actual body image (the own perception of the body at present time) and the ideal body image (the representation of what would be the perfect body for the person, that in Western countries the aim of the comparison is slim and toned) (Kostecka, et al., 2019; Aniulis et al., 2022); in the case of AN, the body image is significantly altered, being the perception of the own body weight and size bigger than in reality is, and it leads to body ruminative thoughts and anxiety about increasing weight. On the other hand, perceptual distortions depend on the environment and context related to the person. For example, an individual sees the reflection of the own body in a mirror, and it elicits body-related cognitions; in this case, a person suffering from AN, in which he/she attends more to the most unattractive parts of the body and where the body image is distorted, will experience stronger negative feelings, higher levels of anxiety and distress than HC (Kostecka et al., 2019; Demartini et al., 2020).

Mancuso (2016) suggested that a person can respond to the anxiety and distress created from the body image beliefs with different coping strategies: a) positive rational acceptance, which considers the positive self-care, rational self-talk and the approval of the self; b) experiential avoidance, which attempts to avoid emotions, situations, or cognitions that are seeing as a threat; and c) appearance-fixing, which tries to modify the body aspects that are perceived as imperfect. The first strategy is considered as adaptative and promoted body satisfaction, and the last two strategies are considered as maladaptive, reinforcing body image dissatisfaction, distress, and anxiety, and being related to body image inflexibility. *Body image inflexibility* is defined as the aversion of an individual to experience negative emotions, bodily sensations, or thoughts about one's body appearance (Sandoz et al., 2013), and it is related to the symptoms of eating disorders (Kostecka et al., 2019).

How body image alteration is developed is explained by Riva (2012), who considers that the egocentric reference frame (the body is experienced from the self, as a first-person experience), and the allocentric reference frame (the body is experienced as a third-person, as an object in the environment) interact with each other. The allocentric representations (knowledge about the body over time) formed in the hippocampus and surrounding areas are generated by the long-term spatial memory, and the egocentric representations (current location and state of the body) in the precuneus are generated by the short-term spatial memory. In this way, he suggests the allocentric lock theory, which considers that when this interaction is impaired (due to a medial temporal lobe alteration), the egocentric representations can't send the updated information to the allocentric representations of the body, so the person experiences the own body as it was before, without the possibility to see how it is now due to the strong allocentric memories (Lander et al., 2020).

As it has been explained, people suffering from AN overestimate their size due to a distortion of the body representation, which is not only limited to body image, if not that it also extends to the body schema. **Body schema** is the internal 3D representation of the own body, which stores and updates the information regarding the size and shape of the body in the space; it is automatically adapted to the possible actions that one situation can require in relation to the own body and the environment (Wignall, Thomas, & Nicholls, 2017). In this way, body schema is the active sensorimotor representation of the body which plans and executes actions (Guardia et al., 2012), and a big quantity of research shows that the motor and spatial navigation of people suffering from AN can be affected by the alteration of the body schema (Beckam et al., 2021).

Body schema accuracy mostly depends on the parietal lobe activity, which provides spatial information of senses and motor behaviours: after right parietal damage, patients neglect the left side of their visual field without being aware of it or they displace to the right the subjective body midline; after left parietal damage, patients suffer from difficulties in planning and executing complex motions and show impairments in action attribution (Wignall, Thomas, & Nicholls, 2017). Nico et al. (2010) investigated this phenomenon in patients with AN, HC, patients suffering from right parietal lesions (RPP) and patients suffering from left parietal lesions (LPP). Participants were sitting down in a chair with goggles synchronized with a LED that was placed in a robotic arm located in front of them; the mechanical arm started to move in a horizontal plane towards the subjects, who were instructed to track the movement of the LED; when the LED was turned off, the shutters of the goggles were closed automatically and the participants had to mentally complete the trajectory of the LED and indicate when it hit their bodies and when it stopped hitting. The results obtained show that HC and LPP estimations of the body boundaries were so close to the real ones, and patients with AN and RPP show a rightward shift of their left body boundary. This finding is in accordance with the role of the parietal lobe in the maintenance of the body schema, which seems to be disturbed in patients with AN.

Motor imagery is a cognitive process in which the performance of a movement is imagined (without its execution). It requires the conscious activation of the brain areas that are related to the preparation and execution of a movement (premotor and supplementary motor areas, cingulate and parietal cortical areas, basal ganglia, and cerebellum), but it also requires the voluntary inhibition of the movement (DLPFC) (Mulder, 2007; Hardwick et al., 2018). Besides the neural overlap activation between motor execution and motor imagery, the time spent imagining an action is similar to the time needed for the action execution, which is known as mental isochrony (Mulder, 2007). In line with some investigations, the areas that are activated in both, motor imagery and action execution, are structural and functionally involved in the neurobiology of AN (Favaro, et al., 2012).

Guardia et al. (2012) studied the body schema dysfunction in patients with AN, where participants had to represent their own body doing an imaginary movement. In this study, they projected on a wall different door-like apertures that differed in width, with a height of 2 meters and being 5.90 meters far away from the participants; the task of the participants was to imagine themselves walking at a normal speed toward the aperture and say if they could cross the aperture without turning sideways. Patients with AN judged that they couldn't pass through the aperture even when it was wide enough, and their scores correlated with their level of body dissatisfaction and with the duration of their illness; instead, HC could recognize which aperture could pass according to their shoulder width. Consistent with other investigations (Nico et al., 2010; Favaro et al. 2012), the authors suggested that a possible impaired processing in the parietal networks could be the cause of the alteration in the body dimensions.

For the study of AN, different kinds of measures have been used, such as the explicit and implicit tasks. Explicit evaluations are those which directly demand the person an answer; instead, implicit evaluations don't require an introspection process, so the person answered automatically without being aware of the evaluation that is taking place, and without the experimenter asking the questions directly (in this way, there is a low risk of socially desired responses) (Purcell et al., 2018).

To check the importance of why both measures should be used to contrast information, Cserjési et al. (2009) conducted a study where they used explicit and implicit measures in patients with AN and HC. The implicit task consisted in an Affective Priming Task, where the participants were exposed to a fixation point, a prime for 100ms (it could be a body figure of a woman in underweighted, ideal body or overweighted condition), and a final target word for 500ms (it could be a positive or negative word). The explicit task was a body evaluation scale, where participants have to score from 1 ("completely negative") to 7 ("completely positive") the 3 female body figures that were used during the Priming Task. As result, the AN group associated fatness with a more negative value than HC in both, implicit and explicit measures; both groups gave a positive value to the ideal body shape in the implicit task, but in the self-report scale, patients with AN appreciate less the ideal body shape, but they didn't associate underweight body shape with positive values. In general, these associations could be the result of the activation of personal cognitive schemas and memory, where people with AN show a high negative evaluation of overweight.

Until now, different tests have been used to check the ability of patients with AN to mentally stimulate a body movement. These include tasks that are performed through implicit body motion simulations, such as level-2 visuospatial perspective taking (VPT-2) and the mental rotation task of bodies/body parts (Erle et al., 2019), as well as tasks in which participants are explicitly required to imagine themselves performing an action, where particularly the adoption of a kinesthetic/egocentric perspective is asked. In these tests, the kinesthetic motor imagery implies the simulation of the physical and muscular feeling of carrying out an action and it is perceived as more incorporated than visual motor imagery (Lorey et al., 2009).

To clarify the implicit body motion simulations of the previous paragraph, in the mental rotation task the participants are asked to compare stimuli with different degrees of rotation and to conclude if they are the same stimuli or not (observed from a different perspective). There are two types of rotation tasks that we are interested in, which differs in the kind of stimuli that is presented, such as bodies or body parts, or 3D objects. Whereas the mental rotation of bodies and body parts task seems to stimulate a motor simulation focus on the body (which normally facilitates performance), the mental rotation of 3D objects is based on a visuospatial strategy with the object as the focus point (Krüger et al., 2014; Amorin et al., 2006). According to this approach, patients with movement disorders such as dystonia, myotonic dystrophy and Parkinson's disease show critical impairment in the mental rotation of body parts (Cona et al., 2020; Fiorio et al.,2006; Amick et al., 2006)

Level 2-VPT is one of the two forms of visuospatial perspective taking, which involves the adoption of someone's else point of view and comprehending "how" the world from that virtual perspective is represented (i.e., you have to say to one person that he has an insect in his left hand, which requires taking the "left" or "right" perspective of the person). The other visuospatial perspective taking is 1-VPT, which reflects understanding "what" is within the line of sight of another person ("in front" and "behind"). VPT-2 required a more complex process, and its performance is predicted by the Theory of Mind. Kessler and Rutherford (2010) carried out an experiment where participants observed an image where one avatar was presented with a table in front of him; in the middle of the table there was a computer with four possible targets positions around it, and the task of the participants was to acquire the avatar's perspective and decide if the target's location was in the left, right (VPT-2), occluded or visible (VPT-1). Participants could be in a congruent or incongruent position with respect to the avatar's sitting position. The results were that: a) there were no differences between "left/right" answers (VPT-2), but "visible" answers were faster than "occluded" (VPT-1); b) VPT-2 response times increase with angular disparity, but not in VPT-1; c) in VPT-2 response times were faster in the congruent than in the incongruent posture in all angular disparities. With these results, it has been seen that the adoption of the point of view of the avatar was easier when the position of the participant matched with the avatar's one, which points out that VPT-2 is an “embodied” process (it relies on the position and action catalogue of the body) where the participant mentally rotates the own body schema into the target’s position.

Lander et al. (2020) assessed the patient’s ability in level 2-VPT using the object-perspective taking test (Hegarty & Waller, 2004). In this test, the participant receives a sheet of paper which contains seven objects in the upper part, and a circle with the name of two objects at the bottom, and the task of the participant is to imagine being in the position of a concrete object facing another object and indicate the direction of a target object. The performance was greater in HC than in patients with AN.

Lastly, two studies included a laterality judgement task to assess the ability of AN patients to mentally rotate human figures, but they found contradictory results (Kaltner & Jensen, 2015; Cipolletta et al., 2017). While Kaltner and Jensen (2015) observed lower mental rotation abilities in HC than in patients with AN (independently of the type of stimulus, a person, or a letter), Cipolletta et al. (2017) observed lower performance in patients with AN. In a study conducted by Campione et al. (2017), where they used a similar laterality assessment task with hand stimuli, they observed that HC rotated images of their own hand faster than someone else’s hand, but patients with eating disorders did not show a difference. Nevertheless, there was no difference between the two groups in their ability to mentally rotate the unfamiliar hand stimuli.

In the present study, we aimed to observe the ability of patients suffering from AN in the mental simulation of movements using different tasks:

- The Mental Chronometry test (Williams et al., 2015), the Test of Ability in Movement Imagery (Madan & Singhal, 2013), and one self-reported-questionnaire, the Vividness of Movement Imagery Questionnaire (Isaac et al., 1986) were used to assess explicit motor imagery abilities, which have never been investigated in AN.

- The 3D objects and human figures test (Alexander & Evardone, 2008) was used to assess the mental rotation abilities.
- Level 2 VPT was assessed with the Object-Perspective Taking Test (Hegarty & Waller, 2004).

Due to the possible implication of body schema in AN, our hypotheses are:

1) Patients with AN show greater difficulty than HC in performing motor imagery tasks, particularly under conditions requiring participants to adopt an egocentric/kinesthetic perspective.
2) Patients with AN show selective impairment in the mental rotation of human figures, including the mental simulation of a body-centred movement.
3) The performance is preserved in the mental rotation of 3D objects in patients with AN, which is built on object-based transformations rather than subjective-based transformations.
4) Patients with AN show bigger difficulty than HC in level 2 VPT, as observed by Lander et al. (2009).

METHODS

Participants

In our experiment, the sample included 52 patients with acute AN and 62 healthy controls (HC), all of them females, with a mean age of 19 and 20 years old, respectively.

Patients were enlisted from two different units, the Eating Disorder Unit of the University Hospital of Padova and the Eating Disorder Unit of the San Bortolo Hospital of Vicenza. The full criteria for AN, according to the DSM-V, were fulfilled by all patients. We decided as exclusion criteria for both patients and HC the following: 1) history of alcohol/drug dependence, 2) bipolar disorder or schizophrenia spectrum disorder, 3) mental impairment or learning disabilities, 4) lifetime or current neurological diseases, 5) age under 14 years, and 6) male gender. In addition, we add to the healthy controls the exclusion criteria of a current or lifetime diagnosis of an eating disorder.

The informed consent was given to all participants or to their parents or legal guardians in the case of being underage. The consent was written and signed before starting the tasks. The study was approved by the ethical committee for clinical investigations of Vicenza, Italy.

Procedure

Before starting with the experiment, we gave the participants, parents, or legal guardians the written informed consent. Once it was signed, we asked the participants some questions about their demographic and clinical information (age, education years, current pharmacological treatments, and body mass index -BMI-) and we asked them to complete the State-Trait Anxiety Inventory (STAI, Spielberg et al., 1983).

The data relating to the disease, such as its duration, the lowest weight the person ever reached, and the age of onset were obtained by the experimenter by observing the patient's medical history.

We acquired the hand lateralization index by administering the Edinburgh Handedness Inventory (Oldfield, 1971). Its scores range from +100, denoting consistent right-handedness, to -100, denoting consistent left-handedness. Finally, to assess and exclude participants who presented a mental impairment, we used the Information subtest of the Wechsler Intelligence Scale (Wechsler, 1981, 1991) in participants younger than 21 years old (the children's version if the participant's age was 16 or lower, and the adult version if the participant's age was between 17 and 20 years), while the participants over 20 years old complete the Brief Intelligence Test (Test Breve di Intelligenza, TIB; Colombo, Sartori, &

Brivio, 2002).

After collecting all the previous data, we administered to the participants the following tests and questionnaires: 1) Mental Rotation Test (MRT) with 3D objects and human figures (Alexander and Evardone, 2008); 2) Vividness of Movement Imagery Questionnaire (VMIQ2; Roberts et al., 2008); 3) Mental Chronometry Test (Williams et al., 2015); 4) Perspective Taking/ Spatial Orientation Test (Hegarty & Waller, 2004); and 5) Test of ability in movement imagery (TAMI; Madan & Shighal, 2013). The order of presentation of the tests was randomized between subjects.

In the next section, I will explain all the cognitive measures that were included in the assessment battery.

Measures

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

In our study, we used the revised version of the MRT elaborated by Alexander and Evardone (2008).

The task comprises four practice questions and 23 test questions, of which 11 are presented with 3D block configurations and 12 are presented with human figures (half males and half females, both wearing identical clothes, the same T-shirt and trousers). When the test starts, the participant can see a reference picture in the left part of the screen, and four rotated "response" pictures in the right part of the screen, of which two are identical to the reference picture and the other two are different. The task of the participant is to say what of the four pictures are identical to the reference one (Figure 2).

Only if the participant identifies both identical pictures, the answer is scored as correct. We recorded the correct number of responses and the average time (in seconds) that the participant took to answer both kinds of stimulus, the 3D objects, and the human figures.

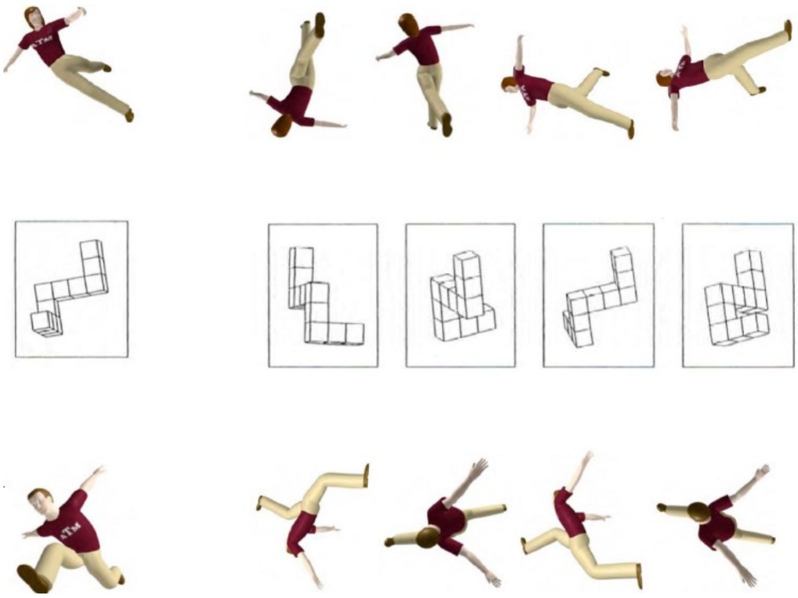

Figure 2. Example of human figures and 3D objects of the MRT. Recovered from "Blocks and bodies: Sex differences in a novel version of the Mental Rotations Test". Alexander and Evardone*,* 2008*, Hormones and behavior, 53*(1), 177-184.

We wanted to consider the accuracy and the execution speed simultaneously, so the proportion of errors and the mean response time were z-standardized to be in the same metric; they were average in an overall performance index, where higher z scores indicated a worse performance.

2. *Vividness of Movement Imagery Questionnaire (VMIQ-2)*

The VMIQ-2, developed by Roberts et al (2008), is a subjective questionnaire that measures the motor imagery of the participant.

During this test, we provided the participants with a list of 12 items, and they have to watch themselves performing the movement that is being asked (e.g., walking, running, bending to pick a coin, jumping off a high wall, throwing a stone into the water…). Specifically, they were asked to imagine performing the movements depending on three different perspectives: 1) external visual imagery (EV, imagining oneself performing an action from a third-person perspective); 2) internal visual imagery (IV, imagining oneself performing an action from a first-person perspective); and 3) kinesthetic imagery (KI, imagining the physical and muscular sensation of performing the action). For each item and perspective, the participants answered the vividness of the movement that was imagined on a 5-point Likert scale, where 1 corresponds to “Perfectly clear and vivid as normal vision” and 5 to “No image at all, you only know that you are thinking of the skill”. Each subscale (EV, IV and KI) score ranges from 12 to 60.

3. *Mental Chronometry Test*

The Mental Chronometry Test that we used was adapted from the one used by Williams et al. (2015).

The test was composed of four blocks: in all blocks, the participants had to read the description of a movement (which was taken from the Movement Imagery Questionnaire-3, Williams et al., 2012). After, participants were asked to physically perform the action that was described and to imagine the movement using different perspectives: 1) external visual imagery (EV), 2) internal visual imagery (IV), and 3) kinesthetic imagery (KI). Fifty per cent of the participants began by imagining the movement, and the other fifty per cent started with the physical performance of the action. The experimenter recorded the time that the participant took to physically perform the action, while the participant himself recorded the time that he/she needed to imagine the movement according to the different perspectives.

For each perspective and movement, it was calculated a discrepancy score by subtracting the “imaging” time from the “physical execution” time. The absolute discrepancy scores were used to calculate an average discrepancy score for each perspective.

4. Perspective Taking/Spatial Orientation Test

The Perspective Taking/ Spatial Orientation Test that we have used was the revised version developed by Hegarty and Waller (2004).

The task was composed of one example question and 12 test questions. In each of the twelve questions, it was presented a map with 7 objects, and the participants had to imagine being at the position of one of the objects (station point) facing another object (facing object). As shown in Figure 3, the participants had to draw an arrow in a circle indicating the position of a third object that is asked. Inside the circle, the reference points are the station point (in the center) and the facing object (drawn as an arrow pointing vertically up.

To acquire the data, we recorded the total time (in minutes) that the participants took to complete the trials and the mean deviation (in degrees) from the correct response. As we did for the MRT, both dependent variables were z-standardized and averaged to obtain a unique performance index (it considers the response time and the accuracy of the response). Higher z scores indicate worse performance.

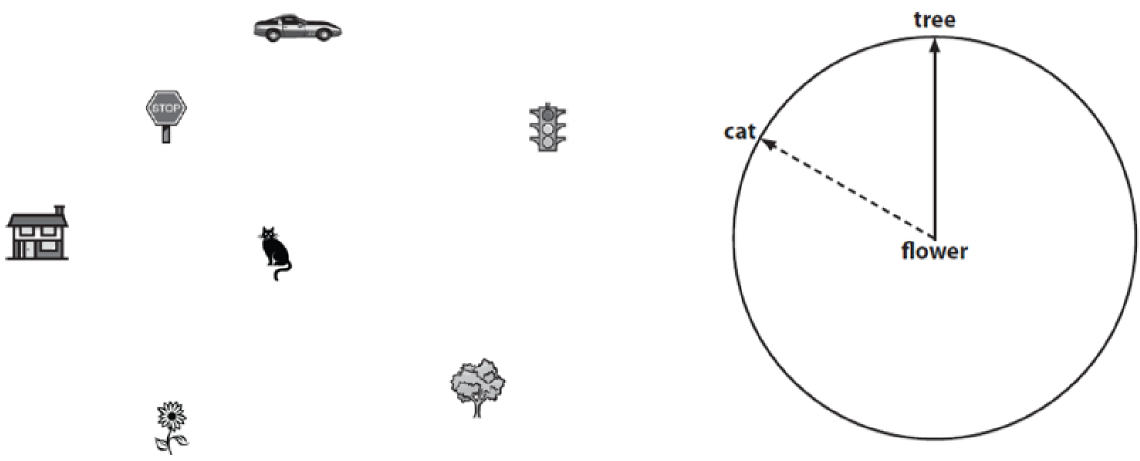

Figure 3. Example of an item in the Object Perspective Taking Test. The instructions were "Imagine you are standing at the flower and facing the tree. Point to the cat". The participant's response is the dashed arrow (direction to the cat). From "A dissociation between mental rotation and perspective-taking spatial abilities" M. Hegarty., & D. Waller, 2004, *Intelligence, 32(2).* https://hegarty-lab.psych.ucsb.edu/sites/default/files/2020-04/PTSOT.pdf

5. *Test of ability in movement imagery (TAMI).*

TAMI was developed by Madan and Singhal (2013), and it objectively assesses motor imagery abilities.

The test contains one example question and 10 test questions. In all questions, participants had only to imagine the movement instruction that they have read, and not move. All test questions started with the same instruction, “1. Stand up straight with your feet together and your hands at your sides”, and after, they had to read other 4 instructions of four different movements (i.e., “2. Step your left foot 30 cm backward; 3. Turn your torso 60° to the right; 4. Raise your left arm 90° to the side; 5. Raise your right arm upward 180°”). Once they have read an instruction, they have to close their eyes and imagined it, doing it for each instruction. Finally, after imagining the movements, it is shown five different images, as it is presented in Figure 4, and the participants have to choose the image that corresponds to the final position of the imagined body, or “none of the above”, or “unclear”.

The correct answer for each question is scored from 1 to 5, conformed to its difficulty (Madam & Singhal, 2014). The total scores range from 0 to 24 points.

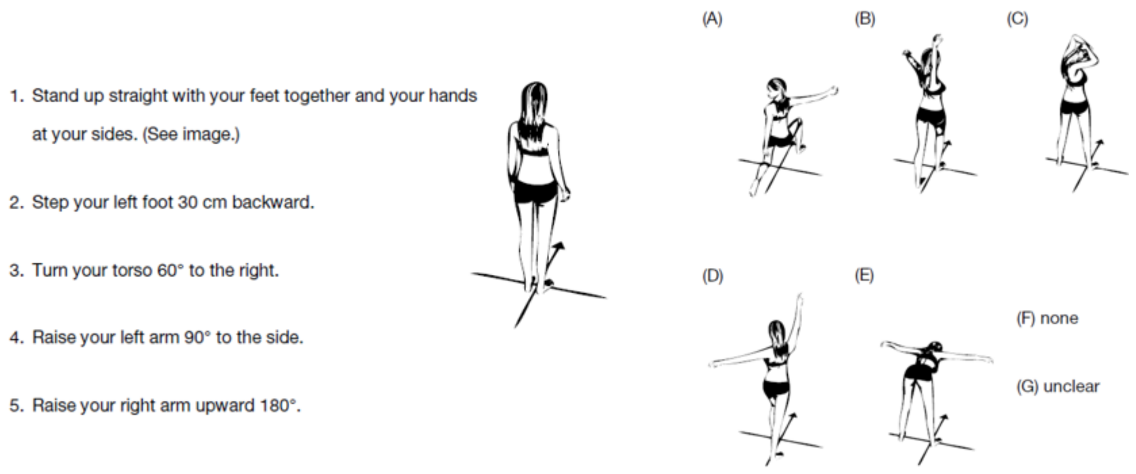

Figure 4. Example of a question of the TAMI test. From “Introducing TAMI: An objective test of ability in movement imagery. Journal of motor behavior” C. R. Madan, & A. Singhal, 2013, *Journal of motor behavior, 45*(2), 153-166.

Statistical analysis

We used the non-parametric Mann-Whitney U test to see the differences between groups in cognitive and demographic measures.

For the MRT, Mental Chronometry Test, and VMIQ2, which involve different within-subject conditions, we conducted a repeated measure non-parametric Aligned Rank Transform (ART) ANOVA to check the main effects and the significance of the group by condition interaction (Wobbrock et al., 2011).

Relationships between clinical data (BMI, age of onset, duration of the illness, lower body weight, 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. False Discovery Rate (FDR) was used to correct correlations for multiple comparisons, 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

All the data related to demographic and clinical characteristics of patients with AN and HC are summarized in Table 2. We can observe that patients with AN present lower BMI and a higher degree of anxiety state and anxiety trait compared to HC. In relation to handedness, patients with AN showed significantly lower scores at the Edinburgh Handedness Inventory, suggesting lower right-handedness than HC.

Table 2.

Demographic and clinical data of patients with AN and HC.

	AN Mean (SD)	**HC 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)	-	-
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)**

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

Body schema-related cognitive measures

Between-subjects analyses

Response time and mean accuracy scores of the cognitive tests and questionnaires from the patients with AN and HC are shown in Table 3. Patients with AN displayed lower accuracy than HC in the MRT of human figures, the Spatial Orientation Test, and in the Test of Ability in Movement Imagery. The results for the MRT and the Spatial Orientation Test were also confirmed by the analyses conducted on z scores, which considered accuracy and response times conjointly. Furthermore, patients reported significantly lower vividness of imagined movement according to the kinesthetic imagery and internal visual perspectives, compared to HC.

Table 3.

Results of the analysis of the Cognitive Measures.

	AN Mean (SD)	HC Mean (SD)	U (*p*)
TAMI tot	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)**
	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)**

Note. 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.

Within-subjects analyses

A significant main effect of group F=4.91, p=.029) and a significant main effect of condition (F=93.51, p<.001) were reported by the repeated measure non-parametric ANOVA conducted on MRT accuracy scores. Even though, the interaction group by condition was not statistically significant (F=0.01, p=.956).

A significant main effect of condition (F=47.03, p>.001) and a significant condition by group interaction (F=5.22, p=.024) were revealed by the repeated-measure analysis conducted on MRT response times. Specifically, as represented in Figure 5.a., both HC and patients with AN were faster in responding to human figures than to 3D objects, but, even so, patients showed a lower advantage in response time compared to HC. No significant main effect of group appeared (F=1.37, p=.244).

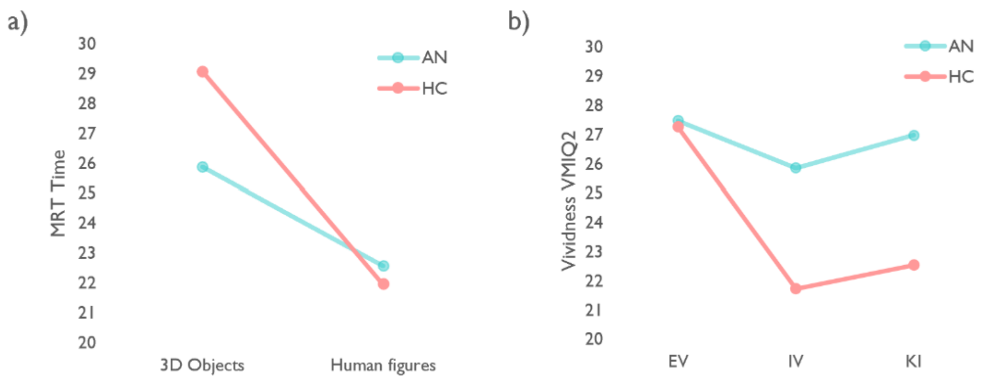

Figure 5. Graph a) MRT response time results in 3D objects and human figures tasks in HC (red line) and patients with AN (blue line). Graph b) Responses in the VMIQ2 about the vividness of the movement that has been imagined from different perspectives, the external visual imagery (EV), internal visual imagery (IV) and the kinesthetic visual imagery (KI) in both groups, HC (red line) and patients with AN (blue line). In graph b), higher punctuation means a lower vividness of the movement.

Regarding the mental chronometry task, there was not any significant result: main effect of group (F=.31, p=.582), main effect of condition (F=.198, p=.820), group by condition interaction (F=1.32, p=.271).

According to the VMIQ2 questionnaire, there was a significant main effect of condition (F=9.658, p<.001), a significant group by condition interaction (F=4.75, p=.010), and a trend towards the main effect of group (F=3.37, p=.069). As we can observe in Figure 5.b., both AN patients and HC reported lower vividness (higher scores) of movements imagined according to the external visual perspective, as compared to the internal or kinematic perspective. 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

There were no significant correlations between body schema related to cognitive measures and clinical variables in either the AN patients' group or HC group.

Correlations between different cognitive measures in both HC and patients suffering from AN are reported in Figure 6.

	TAMI tot	MRT obj	MRT hum	S. O.	M. C. EV	M. C. IV	M. C. K	VMIQ2 EV	VMIQ2 IV
HC group									
TAMI tot	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***

	TAMI tot	MRT obj	MRT hum	S. O.	M. C. EV	M. C. IV	M. C. K	VMIQ2 EV	VMIQ2 IV
AN group									
TAMI tot	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***

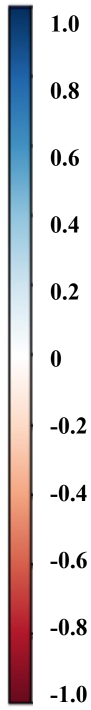

Figure 6. Correlations between cognitive measures in HC and patients with AN using the Spearman Rho, where 1 indicates a perfect positive correlation, 0 a no correlation, and -1 a perfect negative correlation.

DISCUSSION

The present thesis has discussed the results of our investigation, which was done in a sample of 52 patients with acute AN and 62 healthy controls, with the purpose of evaluating the motor imaginary abilities of both groups using different techniques: two tasks that implicitly demand to imagine a simulation of a body movement (the Perspective Taking/Spatial Orientation Test and the mental rotation of human figures) and three tests of explicit motor imagery (TAMI, VMIQ2, and Mental Chronometry Test).

The obtained results show that HC presents lower difficulty than patients with AN in explicitly imagining movements, which we have observed with the VMIQ2 and the TAMI, in mentally rotating human figures, and in adopting a different egocentric visuospatial perspective. There were no significant differences between HC and patients with AN in the Mental Chronometry Test.

Together, our findings are in accordance with the hypothesis of an alteration in the ability to mentally represent movements in AN. But if we look at each test individually, we can observe different findings.

Firstly, the total score of TAMI, a measure that assesses the ability of a person to imagine body movements (Madan & Singhal, 2013), was higher in HC than in patients with AN, indicating that patients with AN show an impairment in the ability to mentally imagine body movements.

The second explicit test used to measure the vividness of motor imagery movements was the VMIQ-2 (Roberts et al. 2008). Our results show that patients with AN have greater difficulties than HC in imagining the vividness of a movement when they are asked to use the kinesthetic or internal perspectives, but no differences are observed between patients with AN and HC when they have to imagine the movement from an external perspective, which could suggest that motor imagery variations are fixed in the body schema. Following these results, Stinear et al. (2006) described how motor imagery can be divided into kinesthetic motor imagery and visual motor imagery, where the subject feels that he/she is performing the movement with the sensory feelings that it implies during the kinesthetic task, while during the visual motor imagery the subject feels the performance of the movement from a distance perspective (third-person perspective, EV); indeed, their results suggest that kinesthetic imagery could be more effective for motor learning than a third-person perspective. In addition, Lorey et al. (2009) suggest that EV implies a visual and abstract representation of movements, while first-person motor imagery implies the formation of an internal motor plan based on the body schema. Following our results and taking in consideration the conclusions of the other investigations, the better performance of HC using the first-person perspective could indicate that patients with AN show greater difficulty in using their body schema to solve explicit motor imagery tasks, and they perhaps represent movements in a visual way, rather than kinesthetic.

The difficulties observed in patients with AN related to body schema are also supported by the MRT results, where patients with AN and HC didn't show differences in mentally rotate 3D objects, but they showed a difference in mentally rotate human figures, displaying worse accuracy the patients with AN than HC. When we observed the results of the groups, both have an advantage in the human figures task, but HC shows a greater advantage than patients with AN. This is not the first time that these results are obtained; Lander et al. (2020) did not observe significant differences in the mental rotation of 3D objects in the MRT between HC and patients with AN, and Cipolletta et al. (2017) tested the Manikin's test (the person has to say in what hand a man is holding the ball from different perspectives) and the mean score of the HC was higher than the patients with AN.

Instead, a different result has been reported by Karltner and Jansen (2015) who performed a study with patients with AN, HC and elite athletes. Their task was to decide if the rotated human figure stimulus was equal or different to the comparison stimulus; the obtained results showed that there was no significant difference in the accuracy response in all groups, but in the response time, patients with AN and athletes were faster than the control group. They explained that the improvement of the visual-spatial ability could be due to the higher body awareness of patients with AN (in a negative way) or athletes (in a positive way), but they also added that this could be due to the higher ambition of these two groups.

However, it has to be noted that the different results could be due to the BMI of the participants: in Kaltner and Jansen (2020), indeed, the mean BMI of patients with AN was 18,08; while in Cipolleta et al. (2017) and in our study it was lower, 16,87 and 15,87 respectively. This could imply that visuospatial abilities impairments and body schema alterations are only present in underweight patients in the acute phase of the disorder. For future research, it would be interesting to understand better how body schema is affected in people suffering from AN, and if there is a minimum of body weight loss needed to detect the beginning of the alteration.

The Perspective Taking/Spatial Orientation Test results display that HC performed better than patients with AN, meaning that patients with AN have greater difficulties in adopting a diverse visuospatial perspective than HC.

Our results in the Perspective Taking/Spatial Orientation Test and in MRT with 3D objects are consistent with the results of Lander et al. (2020). The egocentric reference frame is measured with the Perspective Taking/Spatial Orientation Test (HC show a better performance than patients with AN), and the allocentric reference frame is measured with the MRT with 3D objects (no differences have been found between HC and patients with AN). According to the results, the allocentric frame was conserved (long-term knowledge of the body), whereas the egocentric frame was impaired (actual body state and location of the body), which could support the allocentric lock hypothesis (Riva, 2012), where patients with AN perceive their body larger than it is due to the failure to update the actual information of the body in the long-term memory, which doesn't allow to perceive the actual body size and patients see themselves as they were in the past.

As it was said in the introduction, Guardia et al. (2010) observed that patients with AN significantly overvalued their shoulder width to cross the projected aperture on the wall, and they show a positive correlation between the duration of the disease and the passability ratio (the longer the process of AN indicates a greater passability ratio). To this fact, they explained that the body schema could not have been updated, or that the longer the disease, the worse the brain makes the estimation of the body over time.

A possible approach that has been tested to reduce body schema alteration in patients with AN involves the use of virtual reality (VR) or multisensory stimulation (Riva, Malighetti, & Serino, 2021). In the study of Keizer et al. (2014), for example, they induced participants to the "Rubber Hand Illusion" (RHI), where individuals are exposed to receiving a touch in an artificial hand, but they perceive it in their real hand, which is hidden. Before and after the RHI, participants had to estimate the size of the rubber hand and their own hand. As results, patients with AN experienced the ownership of the rubber hand stronger than HC; before the RHI, AN patients overestimated the width of their hands, but after the illusion, they estimate the width more accurately. The strongest experience of ownership perceived by the AN patients could mean that they have a higher malleable body representation.

In another study of Keizer et al. (2016), they wanted to observe if this finding could be found with a Full Body Illusion (FBI), where they induced a bodily illusion and the participants embodied a virtual body completely different from theirs (the experimenter was touching their abdomen with a brush, and it could be synchronized on time -tactile experience and VR at the same time- or asynchronized -tactile experience is received before the VR shows it-); before and after the FBI, participants had to estimate the width and circumference of some parts of their body (shoulders, abdomen and hips). In this case, AN patients overestimate their body circumference and body width before the FBI, but after the FBI patients with AN showed a decrease in misestimation in all body parts; even though, they still showed a larger overestimation compared to HC, which implies that the body size has not been normalized. The subjects completed a follow-up measure (2h 45min after the FBI), and AN patients showed a normalized estimation of their shoulder width and circumference, but not in the abdomen and hip. Considering these results, the FBI alters how participants perceive the size of their body, and more importantly, it shows that body image alterations of patients with AN are malleable and they persist over a period of time. This could be useful for future treatments in AN, where the cure of body disturbances are challenging and difficult to treat. In addition, it would be interesting to observe if the reduction in the body schema alterations are associated with an improvement in the motor imagery of the person after the induction of bodily illusions.

Despite our results, there are some limitations that should be known about the study. First of all, it is a cross-sectional study in which only patients in the acute phase of AN were selected, so we couldn't assess the effects of weight recovery on the cognitive functions that were evaluated. In the second place, only female participants were recruited, so the results cannot be generalized to the male population.

Nevertheless, our results have revealed that patients with AN show an alteration in motor imagery, being the study with the largest sample size studied in this area. The results obtained show that this alteration is not only present in the explicit motor imagery, if not that the implicit tasks have shown an alteration in the egocentric mental transformation of the body, suggesting that there could be an association between body image disturbances and motor imagery.

Finally, AN is a complex disease, where some factors such as traumatic experiences, familial predisposition, alterations in cognition, perception, emotions and body image, or disruption in the neural networks are related to its development and maintenance. Future investigations should be focused in understand better the factors that are part of the AN, understanding better the neurobiology of the disease and using new technologies to develop more effective interventions, promoting therapeutical methods with a shorter response time and positive outcomes.

BIBLIOGRAPHY

1. Alexander, G. M., & Evardone, M. (2008). Blocks and bodies: Sex differences in a novel version of the Mental Rotations Test. *Hormones and behavior, 53*(1), 177-184.
2. American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (5th ed.), Arlington, VA: American Psychiatric Association.
3. Amick, M. M., Schendan, H. E., Ganis, G., & Cronin-Golomb, A. (2006). Frontostriatal circuits are necessary for visuomotor transformation: mental rotation in Parkinson's disease. *Neuropsychologia, 44*(3), 339-349.
4. Anand, P., & Mehler, P. S. (2019). Osteoporosis recovery in severe anorexia nervosa: a case report. *Journal of eating disorders*, *7*, 38. https://doi.org/10.1186/s40337-019-0269-8
5. Aniulis, E., Nicholls, M. E. R., Thomas, N. A., & Sharp, G. (2022). The role of social context in own body size estimations: An investigation of the body schema. *Body Image*, *40*, 351-357. https://doi.org/10.1016/j.bodyim.2022.01.017
6. Aniulis, E., Nicholls, M., Thomas, N. A., & Sharp, G. (2022). The role of social context in own body size estimations: An investigation of the body schema. *Body image*, *40*, 351–357. https://doi.org/10.1016/j.bodyim.2022.01.017
7. Campione, G. C., Mansi, G., Fumagalli, A., Fumagalli, B., Sottocornola, S., Molteni, M., & Micali, N. (2017). Motor-based bodily self is selectively impaired in eating disorders. *PloS one*, *12*(11), e0187342. https://doi.org/10.1371/journal.pone.0187342
8. Cardi, V., Krug, I., Perpiñá, C., Mataix-Cols, D., Roncero, M. & Treasure, J. (2012). *Eur. Eat. Disorders Rev., 20,* 240-245. https://doi.org/10.1002/erv.1155
9. Cipolletta, S., Malighetti, C., Serino, S., Riva, G., & Winter, D. (2017). Intrapersonal, interpersonal, and physical space in anorexia nervosa: a virtual reality and repertory grid investigation. *Psychiatry Research, 252*, 87-93.

10. Colombo, L., Sartori, G., & Brivio, C. (2002). Estimation of intelligence quotient using the TIB (Intelligence Brief Test). *G Ital Psicol, 3*, 613-37.

11. Cona, G., Casagrande, A., Lenzoni, S., Pegoraro, E., Bozzoni, V., Bello, L., Sorarù, G., Botta, A., & Semenza, C. (2020). The Role of Motor System in Mental Rotation: New Insights from Myotonic Dystrophy Type 1. *Journal of the International Neuropsychological Society : JINS*, *26*(5), 492–502. https://doi.org/10.1017/S1355617719001383

12. Cserjési, R., Vermeulen, N., Luminet, O., Marechal, C., Nef, F., Simon, Y., & Lénárd, L. (2010). Explicit vs. implicit body image evaluation in restrictive anorexia nervosa. *Psychiatry Research, 175*(1–2), 148–153. https://doi.org/10.1016/j.psychres.2009.07.002

13. Demartini, B., Nisticò, V., Tedesco, R., Marzorati, A., Ferruci, R., Priori, A., Gambini, O., & Caputo G. B. (2021). Visual perception and dissociation during Mirror Gazing Test in patients with anorexia nervosa: a preliminary study. *Eat Weight Disord, 26,* 1541–1551. https://doi.org/10.1007/s40519-020-00977-6

14. E.K. Sandoz, K.G. Wilson, R.M. Merwin, K.K. Kellum. (2013). Assessment of body image flexibility: The Body Image-Acceptance and Action Questionnaire. *Journal of Contextual Behavioral Science, 2*, 39-48. 10.1016/j.jcbs.2013.03.00

15. Eddy, K. T., Tabri, N., Thomas, J. J., Murray, H. B., Keshaviah, A., Hastings, E., Edkins, K., Krishna, M., Herzog, D. B., Keel, P. K., & Franko, D. L. (2017). Recovery From Anorexia Nervosa and Bulimia Nervosa at 22-Year Follow-Up. *The Journal of clinical psychiatry, 78*(2), 184–189. https://doi.org/10.4088/JCP.15m10393

16. Erle T. M. (2019). Level-2 visuo-spatial perspective-taking and interoception - More evidence for the embodiment of perspective-taking. *PloS one*, *14*(6), e0219005. https://doi.org/10.1371/journal.pone.0219005

17. Favaro, A., Santonastaso, P., Manara, R., Bosello, R., Bommarito, G., Tenconi, E., & Di Salle, F. (2012). Disruption of visuospatial and somatosensory functional connectivity in anorexia nervosa. *Biological Psychiatry, 72*(10), 864-870.

18. Fiorio, M., Tinazzi, M., & Aglioti, S. M. (2006). Selective impairment of hand mental rotation in patients with focal hand dystonia. *Brain, 129*(1), 47-54.

19. Garner D. M. (1993). Pathogenesis of anorexia nervosa. *Lancet (London, England)*, *341*(8861), 1631–1635. https://doi.org/10.1016/0140-6736(93)90768-c

20. Gibson, D., Workman, C., & Mehler, P. S. (2019). Medical Complications of Anorexia Nervosa and Bulimia Nervosa. *The Psychiatric clinics of North America*, *42*(2), 263–274. https://doi.org/10.1016/j.psc.2019.01.009

21. Guardia, D., Lafargue, G., Thomas, P., Dodin, V., Cottencin, O., & Luyat, M. (2010). Anticipation of body-scaled action is modified in anorexia nervosa. *Neuropsychologia, 48*(13), 3961–3966. https://doi.org/10.1016/j.neuropsychologia.2010.09.004

22. Hardwick, R. M., Caspers, S., Eickhoff, S. B., & Swinnen, S. P. (2018). Neural correlates of action: Comparing meta-analyses of imagery, observation, and execution. Neuroscience & *Biobehavioral Reviews, 94*, 31-44.

23. Hegarty, M., & Waller, D. (2004). A dissociation between mental rotation and perspective-taking spatial abilities. *Intelligence, 32*(2), 175-191.

24. Kaltner, S., & Jansen, P. (2015). Does body awareness influence visual spatial intelligence?. International Journal of Learning, *Teaching and Educational Research, 13*(4).

25. Keizer, A., Smeets, M. A., Dijkerman, H. C., van Elburg, A., & Postma, A. (2012). Aberrant somatosensory perception in Anorexia Nervosa. *Psychiatry research*, *200*(2-3), 530–537. https://doi.org/10.1016/j.psychres.2012.05.001

26. Keizer, A., van Elburg, A., Helms, R., & Dijkerman, H. C. (2016). A Virtual Reality Full Body Illusion Improves Body Image Disturbance in Anorexia Nervosa. *PloS one*, *11*(10), e0163921. https://doi.org/10.1371/journal.pone.0163921

27. Keski-Rahkonen, A., & Mustelin, L. (2016). Epidemiology of eating disorders in Europe: prevalence, incidence, comorbidity, course, consequences, and risk factors. *Current opinion in psychiatry*, 29(6), 340–345. https://doi.org/10.1097/YCO.0000000000000278

28. Kessler, K., & Rutherford, H. (2010). The two forms of visuo-spatial perspective taking are differently embodied and subserve different spatial prepositions. Frontiers in Psychology, 1, 213.

29. Kostecka, B., Kordynska, K. K., Murawiec, S., & Kucharska, K. (2019). Distorted body image in women and men suffering from Anorexia Nervosa - a literature review. *Archives of Psychiatry and Psychotherapy*, *21*(1), 13-21. https://doi.org/10.12740/APP/102833

30. Krüger, M., Amorim, M. A., & Ebersbach, M. (2014). Mental rotation and the motor system: Embodiment head over heels. *Acta psychologica, 145*, 104-110.

31. Lander, R., Heled, E., & Gur, E. (2020). Executive functioning and spatial processing in anorexia nervosa: an experimental study and its significance for the allocentric lock theory. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity, 25*(4), 1039-1047.

32. Lorey, B., Bischoff, M., Pilgramm, S., Stark, R., Munzert, J., & Zentgraf, K. (2009). The embodied nature of motor imagery: the influence of posture and perspective. *Experimental brain research, 194*(2), 233-243.

33. Madan, C. R., & Singhal, A. (2013). Introducing TAMI: An objective test of ability in movement imagery. *Journal of motor behavior, 45*(2), 153-166.

34. Madan, C. R., & Singhal, A. (2014). Improving the TAMI for use with athletes. *Journal of Sports Sciences, 32*(14), 1351-1356

35. Magrini, M., Curzio, O., Tampucci, M., Donzelli, G., Cori, L., Imiotti, M. C., Maestro, S., & Moroni, D. (2022). Anorexia Nervosa, Body Image Perception and Virtual Reality Therapeutic Applications: State of the Art and Operational Proposal. *International journal of environmental research and public health*, *19*(5), 2533. https://doi.org/10.3390/ijerph19052533

36. Magrini, M., Curzio, O., Tampucci, M., Donzelli, G., Cori, L., Imiotti, M. C., Maestro, S., & Moroni, D. (2022). Anorexia Nervosa, Body Image Perception and Virtual Reality Therapeutic Applications: State of the Art and Operational Proposal. *International journal of environmental research and public health*, *19*(5), 2533. https://doi.org/10.3390/ijerph19052533

37. Mancuso S. G. (2016). Body image inflexibility mediates the relationship between body image evaluation and maladaptive body image coping strategies. *Body image*, *16*, 28–31. https://doi.org/10.1016/j.bodyim.2015.10.003

38. Mulder T. (2007). Motor imagery and action observation: cognitive tools for rehabilitation. *Journal of neural transmission (Vienna, Austria : 1996)*, *114*(10), 1265–1278. https://doi.org/10.1007/s00702-007-0763-z

39. Nico, D., Daprati, E., Nighoghossian, N., Carrier, E., Duhamel, J., & Sirigu, A. (2010). The role of the right parietal lobe in anorexia nervosa. *Psychological Medicine, 40*(9), 1531-1539. doi:10.1017/S0033291709991851

40. Purcell, J. B., Winter, S. R., Breslin, C. M., White, N. C., Lowe, M. R., & Branch Coslett, H. (2018). Implicit Mental Motor Imagery Task Demonstrates a Distortion of the Body Schema in Patients With Eating Disorders. *Journal of the International Neuropsychological Society : JINS*, *24*(7), 715–723. https://doi.org/10.1017/S1355617718000371

41. Riva G. (2012). Neuroscience and eating disorders: the allocentric lock

hypothesis. *Medical hypotheses*, *78*(2), 254–257. https://doi.org/10.1016/j.mehy.2011.10.039

42. Riva, G., Malighetti, C., & Serino, S. (2021). Virtual reality in the treatment of eating disorders. *Clinical psychology & psychotherapy*, *28*(3), 477–488. https://doi.org/10.1002/cpp.2622
43. Roberts, R., Callow, N., Hardy, L., Markland, D., & Bringer, J. (2008). Movement imagery ability: development and assessment of a revised version of the vividness of movement imagery questionnaire. *Journal of sport & exercise psychology*, *30*(2), 200–221. https://doi.org/10.1123/jsep.30.2.200
44. Seitz, J., Bühren, K., von Polier, G. G., Heussen, N., Herpertz-Dahlmann, B., & Konrad, K. (2014). Morphological changes in the brain of acutely ill and weight-recovered patients with anorexia nervosa. A meta-analysis and qualitative review. *Zeitschrift fur Kinder- und Jugendpsychiatrie und Psychotherapie*, *42*(1), 7–18. https://doi.org/10.1024/1422-4917/a000265
45. Spielberger, C. D., Gorsuch, R. L., Lushene, R. E., Vagg, P. R., & Jacobs, G. A. (1983). State-trait anxiety inventory. Palo Alto. CA: Mind Garden
46. Stinear, C. M., Byblow, W. D., Steyvers, M., Levin, O., & Swinnen, S. P. (2006). Kinesthetic, but not visual, motor imagery modulates corticomotor excitability. *Experimental brain research*, *168*(1-2), 157–164. https://doi.org/10.1007/s00221-005-0078-y
47. Sullivan P. F. (1995). Mortality in anorexia nervosa. *The American journal of psychiatry*, *152*(7), 1073–1074. https://doi.org/10.1176/ajp.152.7.1073
48. UK sport world class success. (2007*). Eating disoders in sport: a guideline framework for practiones working with high performance atheletes*. UK sport world class success. https: https://www.uksport.gov.uk/~/media/files/resources/eating_disorders_in_sport.pdf

49. Van Eeden, A. E., van Hoeken, D., & Hoek, H. W. (2021). Incidence, prevalence and mortality of anorexia nervosa and bulimia nervosa. Current opinion in psychiatry, 34(6), 515–524. https://doi.org/10.1097/YCO.0000000000000739

50. Wechsler, D. WAIS-R manual: Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corporation, 1981.

51. Wignall, S. J., Thomas, N. A., & Nicholls, M. (2017). Fat or fiction? Effects of body size, eating pathology, and sex upon the body schema of an undergraduate population. *Body image*, *23*, 135–145. https://doi.org/10.1016/j.bodyim.2017.09.004

52. Williams, S. E., Guillot, A., Di Rienzo, F., & Cumming, J. (2015). Comparing self-report and mental chronometry measures of motor imagery ability. *European Journal of Sport Science, 15*(8), 703-711.

53. Williams, Sarah & Cumming, Jennifer & Ntoumanis, Nikos & Nordin-Bates, Sanna & Ramsey, Richard & Hall, Craig. (2012). Further Validation and Development of the Movement Imagery Questionnaire. *Journal of sport & exercise psychology, 34*, 621-46. 10.1123/jsep.34.5.621.

54. Wobbrock, J.O., Findlater, L., Gergle, D. and Higgins, J.J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11). Vancouver, British Columbia (May 7-12, 2011). New York: ACM Press, pp. 143-146.

APPENDIX

PROTOCOLLO DI STUDIO

Oggetto: Protocollo di studio

Titolo Protocollo	Valutazione delle abilità di immaginazione motoria e visuospaziale in pazienti con Anoressia Nervosa
Numero Eudract (*se applicabile*)	Non applicabile
Codice Protocollo	
Versione e data	Versione 1, 23/07/2021

Introduzione

Le pazienti che soffrono di Anoressia Nervosa presentano solitamente insoddisfazione nei confronti del proprio corpo, spesso accompagnata da una distorsione sia dell'immagine che delloschema corporeo. Diversi studi di neuroimaging hanno mostrato come la rappresentazione dello schema corporeo venga costantemente aggiornata a livello del lobo parietale destro attraverso l'integrazione di input sensoriali di diversa natura. Secondo la teoria dell'embodiment, l'esecuzione di diverse funzioni cognitive di ordine superiore coinvolge il sistema sensomotorio el'attivazione dello schema corporeo. Tra queste, l'immaginazione motoria, il perspective-taking visuospaziale e la rotazione mentale di immagini di corpi o parti del corpo.

Obiettivi e scopi

L'obiettivo di questo studio è quello di indagare le abilità di immaginazione motoria, perspective-taking visuospaziale e rotazione mentale di corpi nelle pazienti con disturbo dell'alimentazione. Poiché si pensa che queste funzioni siano "embodied" e risiedano nel lobo parietale destro, potrebbero essere alterate nelle pazienti con AN ed avere un ruolo nelle difficoltà visuospaziali e di cognizione sociale spesso osservate in queste pazienti.

Partecipanti

100 donne con una diagnosi di anoressia nervosa secondo il DSM 5 e 100 controlli sani

verrannoreclutati per lo studio. I criteri di esclusione per tutti i partecipanti sono: età inferiore ai 14 anni,disturbi neurologici presenti o passati, storia di disturbi psicotici o abuso di sostanze. Criteri di esclusione per i controlli sani sono: diagnosi di disturbo alimentare presente o passato, storia di altri disturbi psichiatrici.

Reclutamento

Le pazienti verranno reclutate presso il Centro di riferimento provinciale per i disturbi del comportamento alimentare di Vicenza e presso il Centro Regionale per i Disturbi del Comportamento Alimentare di Padova.

I controlli sani verranno reclutati online tramite social media (es. Facebook, Instagram) o tramitecontatto diretto coi ricercatori.

I ricercatori coinvolti nello studio forniranno il foglio informativo ed una checklist relativa a criteridi inclusione ed esclusione ai potenziali partecipanti via email. I potenziali partecipanti avranno modo di richiedere ulteriori informazioni relative allo studio e se soddisfatti, ed elegibili per lo studio, verrà inviata loro una mail con i link per accedere ai test online e verrà fissato un appuntamento per lo svolgimento dei test in presenza.

Procedura

Ai partecipanti verra' richiesto di completare alcuni questionari online relativi a caratteristiche demografiche, umore e comportamento alimentare. Sempre online, ai partecipanati sarà richiestodi svolgere 3 test computerizzati: un Test di Rotazione Mentale con oggetti 3D e immagini di mani,un test di perspective-taking visuospaziale, e un test di embodiment semantico. In seguito alla compilazione dei questionari e dei test online, ai partecipanti verra' richiesto di recarsi presso il Centro di riferimento provinciale per i disturbi del comportamento alimentare di Vicenza o presso il Centro Regionale per i Disturbi del Comportamento Alimentare di Padova. In presenza, i partecipanti svolgeranno la seconda parte della testistica: un Test di Rotazione Mentale con oggetti 3D e immagini di corpi, un test di Orientamento Spaziale, 2 test di immaginazione motoria,1 questionario di immaginazione visiva e 1 questionario di immaginazione motoria.

STRUMENTI USATI:

I dati verranno raccolti utilizzando i seguenti strumenti:

- Questionario demografico: per la raccolta di informazioni demografiche (età, genere,anni di istruzione, stato attuale dell'impiego, status sociale) ed informazioni relative al benessere psicologico e fisico (storia pregressa o attuale di problemi psichiatrici e/o malattie fisiche croniche)
- Depression Anxiety Stress Scales-21 (versione italiana validata da Bottesi et al., 2015):domande relative ad ansia, stress e depressione.
- Eating Disorder Examination Questionnaire (EDE-Q 6.0, Versione Italiana, Calugi et al., 2016): il questionario valuta la psicopatologia del comportamento alimentare e fornisce unpunteggio globale e quattro punteggi a sottoscale specifiche: restrizione, preoccupazione relativa all'alimentazione, preoccupazione relativa alla forma corporea, preoccupazionerelativa al peso.
- Body Attitude Test: un questionario di 20 item progettato per indagare il rapporto con il proprio corpo e l'insoddisfazione corporea nelle pazienti con disturbi del comportamentoalimentare.
- Test di Rotazione Mentale con oggetti 3D e immagini di mani (Cona et al., 2016). Il test è computerizzato e accessibile online tramite link. Ai partecipanti verranno mostrate due immagini e dovranno decidere, il più velocemente possibile, se si tratta dello stesso oggetto visto da prospettive differenti o se uno è la versione speculare dell'altro. Verrannovalutate l'accuratezza e i tempi di reazione.
- Test di perspective-taking visuospaziale (Erle, 2019). Il test è computerizzato e accessibileonline tramite link. Ai partecipanti verrà chiesto di decidere, il più velocemente possibile, se un oggetto si trova alla destra o alla sinistra di un avatar, presentato a diverse disparità angolari rispetto al partecipante. Verranno valutate l'accuratezza e i tempi di reazione.
- Embodiment Verbal Semantic Test (Berges et al., 2003). Il test è computerizzato e accessibile online tramite link. Ai partecipanti verrà mostrata un'immagine di un movimento e poi la descrizione verbale di un

movimento e dovranno decidere, il più
velcemente possibile se l’immagine e la scritta descrivono lo stesso movimento. Verrannovalutate l’accuratezza e i tempi di reazione.

- Test di Rotazione Mentale con oggetti 3D e immagini di corpi (Alexander e Evardone, 2007). Il test sarà svolto carta e penna in presenza. Ai partecipanti verrà mostrata un’immagine di riferimento e 4 immagini target. Il compito del partecipante è quello di individuare le 2 immagini target che raffigurano lo stesso oggetto rappresentato nell’immagine di riferimento ma visto da prospettive diverse. Verranno valutate l’accuratezza e i tempi di reazione.
- Spatial Orientation Test (Hegarty e Waller, 2004). Il test sarà svolto carta e penna in presenza. Ai partecipanti verrà mostrata una mappa con alcuni oggetti, verrà chiesto loro di assumere la posizione di uno di questi oggetti di essere rivolti verso un secondo oggettoe di indicare, disegnando una freccia all’interno di un cerchio, la posizione di un terzo oggetto. Verranno valutate l’accuratezza e i tempi di reazione.
- Test of Ability in Movement Imagery (Madan, 2013). Il test sarà svolto carta e penna in presenza. Ai partecipanti verrà chiesto di immaginare una sequenza di movimenti, letta adalta voce dallo sperimentatore. Al termine della sequenza il partecipante dovrà indicare, tra un set di 5 immagini, quella che rappresenta la posizione finale del movimento che gli èstato fatto immaginare. Verrà valutata l’accuratezza.
- Mental Chronometry Test. Il test sarà svolto carta e penna in presenza. Ai partecipantiverrà chiesto di immaginare e poi svolgere dal vivo alcuni movimenti. Lo sperimentatorecronometrerà il tempo impiegato per svolgere l’azione dal vivo, mentre il partecipante cronometrerà la durata del movimento immaginato.
- Vividness of Movement Imagery Questionnaire, revised version (VMIQ2; Roberts et al., 2008): questionario per la valutazione soggettiva dell’immaginazione motoria. Ai partecipanti viene chiesto di immaginare un determinato movimento e di valutare su unascala da 1 a 5 la vividezza della propria immaginazione
- Vividness of Visual Imagery Questionnaire, revised version (VVIQ; Marks, 1973):

questionario per la valutazione soggettiva dell'immaginazione visiva. Ai partecipanti vienechiesto di immaginare un determinato stimolo e di valutare su una scala da 1 a 5 la vividezza della propria immaginazione

TIPO DI INVASIVITÀ:

Nessuna invasività

TIPO DATI PER TRATTAMENTO:

Dati raccolti in forma confidenziale

PROBLEMI ETICI:

I partecipanti saranno liberi di interrompere la partecipazione allo studio in qualunque momento,senza fornire alcuna motivazione, senza alcuna penalizzazione e ottenendo il non utilizzo dei loro dati. I partecipanti saranno liberi di scegliere di non rispondere ad alcune domande e saranno

liberi di non completare l'applicazione mobile.

MODULO DI CONSENSO INFORMATO
alla partecipazione volontaria ad uno studio clinico spontaneo
(D.M. Salute 15.07.1997)
nonché al trattamento dei dati personali per gli scopi della specifica ricerca

Titolo dello studio: **"Valutazione delle abilità di immaginazione motoria e visuospaziale in pazienti Anoressia Nervosa"**

Io sottoscritto/a

NOME ………………………………………………………..…....…………..…………………………………...

COGNOME ……………………………………………………………..………………………………………….

Dichiaro di aver preso conoscenza e di aver ricevuto copia della *"Lettera informativa per il paziente"* relativa allo studio di cui all'oggetto e di aver ricevuto e compreso tutte le spiegazioni sui presupposti del medesimo e sul suo svolgimento, da parte del

Dottor ………………………………..……………………….... telefono …………………………………………………..

e di aver potuto porre liberamente tutte le domande che ho ritenuto opportune relative a questo studio, domande per le quali ho ricevuto una risposta soddisfacente.

Sono consapevole che l'autorizzazione da me espressa ad utilizzare i miei dati clinici per gli obiettivi dello studio potrà eventualmente essere in seguito ritirata senza fornire giustificazione alcuna e senza che venga in alcun modo modificata la qualità delle cure mediche che mi verranno in futuro prestate.

Sono cosciente del fatto che i miei dati personali possano essere esaminati, nel corso di regolari verifiche, da personale appositamente autorizzato, ma i dati personali, trattati mediante strumenti anche elettronici, rimarranno sempre riservati e non verranno resi pubblici se non (attraverso pubblicazioni o convegni scientifici) in forma rigorosamente anonima e tale da mantenere segreta la mia identità; in ogni caso, il Proponente garantisce che le informazioni saranno trattate senza violare la riservatezza del soggetto e nel rispetto di tutte le vigenti normative in materia di privacy.

In particolare, sono a conoscenza del fatto che la struttura ospedaliera presso la quale sono ricoverato, e il Proponente dello studio al quale acconsento di partecipare, tratteranno i miei dati personali, in particolare quelli sensibili relativi al mio stato di salute, soltanto nella misura in cui essi saranno necessari in relazion all'obiettivo dello studio, e che il **Titolare del trattamento dei dati personali** è l'Azienda U.L.SS. n. 8 Berica, nella persona del suo Direttore Generale pro tempore.

Il **Delegato interno alla gestione delle attività di trattamento dei dati personali e degli adempimenti previsti dal Regolamento UE n. 2016/679**, ai sensi del D.lgs. 196/2003 come modificato dal D.lgs. 101/2018, è il dr.Alessandra Sala, in qualità di Direttore del Centro di riferimento provinciale per i disturbi delcomportamento alimentare di Vicenza.

Inoltre, sono consapevole che i dati che mi riguardano saranno riconducibili ad un *codice identificativo* e soltanto il Medico che mi ha in cura e i soggetti autorizzati per legge saranno in grado di collegare detto codice al mio nominativo.

Sono consapevole che potrò esercitare i diritti di accesso assicurati dalla vigente normativa in materia, per esempio chiedendo di accedere ai miei dati personali, di aggiornarli, di integrarli, di rettificarli, di oppormi al loro trattamento per motivi legittimi etc.…), rivolgendomi direttamente al Medico che mi propone l'adesione a questa ricerca, o per il suo tramite, al Proponente dello studio.

Sono consapevole che agli addetti al monitoraggio, o agli addetti alla verifica, e alle autorità regolatorie sarà consentito l'accesso alla mia documentazione medica originale per una verifica delle procedure dello studio clinico e/o dei dati, senza che ciò possa violare in alcun modo la mia riservatezza, e sono quindi consapevole che firmando il presente modulo autorizzo tale accesso.

Sottoscrivendo tale modulo,

1) accetto di partecipare volontariamente allo studio in questione, dopo essere stato informato di tutti gliaspetti dello studio pertinenti alla mia decisione;
2) acconsento al trattamento dei miei dati personali per gli scopi della ricerca che mi è stata illustrata econ le modalità indicate nella lettera informativa fornitami con il presente documento;
3) mi impegno a consegnare al mio medico di base la lettera fornitami dal Medico Sperimentatore, perinformarlo della mia partecipazione allo studio;
4) prendo atto che ricevo una copia firmata del presente modulo di consenso, unitamente al foglioinformativo.

1) RILASCIO DEL CONSENSO SCRITTO DA PARTE DEL PAZIENTE:

- Il / La paziente

Sig./Sig.ra……………………………………………………… Data ………………………
Firma ……………………………………………………………………

Nel caso di incapacità da parte del paziente di rilasciare il proprio consenso:

- Il Rappresentante legale del paziente *(Genitore esercente la patria potestà su minore, Tutore, Curatore, Amministratore di Sostegno) * / ***

Sig./Sig.ra. ………………………………………………………… Data ………………………

Firma ………………………………………………………………………

** Nel caso in cui sia designato quale rappresentante legale un 'Amministratore di sostegno', il Medico Sperimentatore avrà cura di verificare che l'ordinanza di affidamento da parte del Giudice Tutelare comprenda anche la tutela della salute dell'amministrato.*

*** Quando uno studio clinico (terapeutico o non terapeutico) include soggetti che possano essere arruolati nello studio solo con il consenso del rappresentante legalmente riconosciuto del soggetto (ad esempio: minori o pazienti con demenza grave), il soggetto deve essere informato in merito allo studio nella misura compatibile con la sua capacità di comprensione e, se è in grado, deve firmare e datare personalmente il modulo di consenso informato scritto (D.M. Salute 15.07.1999, punto 4.8.12).*

2) DICHIARAZIONE FINALE DA PARTE DEL MEDICO RESPONSABILE dello studio:

Nominativo, qualifica e unità operativa di appartenenza del Medico responsabile:

………………………………………………………………………………………………….

Io sottoscritto confermo di aver spiegato al paziente la natura, lo scopo e i termini della sua adesione alla ricerca, per quanto attiene in particolare i diritti del paziente in termini di protezione dei dati personali, nonché la possibilità per il paziente di ritirare il consenso precedentemente accordato dietro semplice segnalazione, ed in coscienza ritengo che tali concetti siano stati compresi dall'interessato.

Confermo che il paziente ha liberamente accettato di aderire alla raccolta dati prevista dallo studio firmando il presente modulo di consenso, e che tale modulo sarà archiviato presso la nostra unità operativa come da normativa vigente, e di averne consegnata copia firmata e datata al paziente.

Firma del Medico responsabile ……………………………………..…………………..

Luogo e data ………………..………………………..……..

***