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ORIGINAL RESEARCH

Quality of life is related to the functional connectivity of the default mode network at rest

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Abstract
Quality of life is an important issue concerning people all over the world and affecting patients in the mental health field. When considering the potential neural links between quality of life and the brain, a brain network that comes into mind is the default mode network (DMN). Its architecture and function has been investigated in relation to various research fields including social and emotional cognition, meditation and neuropsychiatric disorders as well as happiness. In this cross-sectional study we investigated the relationship between various quality of life domains (physiological, psychological, social and environmental) and the functional connectivity of the default mode network at rest in a sample of 42 healthy working female managers. The results indicate that there is a significant association between the social quality of life domain and the functional connectivity of the default mode network. Post-hoc analysis revealed that high social quality of life scores were associated with right-left lateral parietal hypoconnectivity. By adopting a wide ranging perspective, our study approaches to fundamental research about quality of life but so far only applied on a female subgroup. As far as we know, it is the first to analyze the neuronal correlates of quality of life in the brain and therefore sets an initial step in its investigation.

Keywords DMN · Quality of life · Connectivity · Women

Introduction

Several factors like health (psychological and physiological), social contacts with other people (friends and family) and environmental conditions (public transport, security, work) determine the overall contentment of an individual's quality of life. The investigation of internal and external factors that influence individual differences in self-perceived quality of life has been a topic of intense research among several populations, including patients, active workers and normal controls of all ages (Marongiu Ivarsson and Ekehammar 2001; Katschnig 2006). Factors disrupting personal quality of life in a negative way can commonly lead to stress and in sustained cases progress to neuropsychiatric disorders, such as depression, schizophrenia, posttraumatic stress disorder (PTSD), and can be associated with altered brain function (Ritsner and Awad 2007).

Particularly, achieving a better understanding of quality of life in the female working population is a growing concern worldwide. Changes in society over the last decades in connection to woman's movement caused women to fulfill several roles in their lifetime. Nowadays, besides working, they care for family, household, cultivate social contacts and care for their physiological and psychological health. Therefore, stress and the lowering of quality of life seems almost to be preprogrammed in this subgroup. Furthermore, there are mental health disorders like depression that are especially pronounced in women and have a high impact on daily well-being and in consequence on perceived quality of life (Hankin and Abramson 2001).

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Sometimes quality of life and well-being are used as synonyms, however they are different concepts according to the World Health Organization (WHO). Well-being represents a general state about feelings as measured by the WHO-5 Well-Being Index (such as cheerful, calm, vigourous, rested, interested in daily life). The index has adequate validity as an outcome measure in clinical trials and has been applied across a wide range of fields (Topp et al. 2015). Quality of life, however, as measured by the WHOQOL-bref, includes several facets in four domains: physical (e.g. pain, rest, activity, medication, ability to work), psychological (e.g. positive/negative feelings, self-steem, self-image, spirituality), social (e.g. relationship, social support, sexual activity) and environmental (e.g. safety, financial resources, opportunities, transportation) (The WHOQOL group 1998), therefore a broader concept than well-being. Different than other studies, we decided to choose quality of life for our analysis. The question rises if these differences can be attributable to brain function.

There is only a small literature analyzing that issue. By using voxel-based morphometry Takeuchi et al. (2014) found an association between quality of life and the regional gray matter volume in regions associated with the evaluation of internally generated information and regions processing negative emotions (left rostrolateral prefrontal cortex, dorsal parts of anterior cingular gyrus and contingent cingulate regions).

There is an empirical evidence that quality of life is often negatively attributed with depression, perceived stress and negative self-referential mental activity (Ritsner and Awad 2007). At the neurobiological level, a large and growing body of literature has suggested alterations in a specific brain network, the so-called default mode network (DMN), as the basis for the disordered self-referential thought (Sheline et al. 2009). The DMN is normally more active during rest and has consistently been implicated in self-referential processing in neuropsychiatric disorders (Sheline et al. 2009) and meditative states (Brewer et al. 2011), as well as in research about social cognition and emotion (Lieberman 2007). Interestingly, increased functional connectivity within regions of the DMN has been negatively associated with people's perceived happiness (Luo et al. 2015). Furthermore Luo and his colleagues recently found a link between two well-being forms (the hedonic (pleasure attainment approach to reach well-being) and eudaimonic (self-realization approach to reach well-being) and the DMN, that they consider as a key network of well-being. Therefore, given the links between self-related processing and DMN functional connectivity, this network seems particularly suited to investigate the complex associations between individual's perception of quality of life and brain function.

The aim of this study was to integrate the analysis of both, brain function and the behavior by examining the relationship between quality of life and the functional connectivity of the DMN at rest in the population of female managers. By separating quality of life in subcategories, namely social, environmental, psychological and physiological spheres it was examined whether one of these domains can somehow be associated with the DMN connectivity in working women. Background for the assumption of altered functional connectivity in different quality of life domains is the consideration that the human brain is able for plasticity and reshaping processes due to external and internal conditions (Davidson and McEwen 2012). The underlying study assumed that quality of life domains, that consist and depend on a large set of external and internal factors will also be related with the function of brain circuits, such as the DMN. Thus, we hypothesize that changes in the self-evaluation of quality of life are associated with functional changes of the DMN connectivity. More specific we assume that higher quality of life scores will be associated with lower functional default mode network connectivity. To test our hypothesis we choose to apply a recently elaborated method called Multivariate Distance Matrix Regression (MDMR) (McArtor et al. 2017) that allowed us to statistically elaborate whether the behavioral measurements (WHOQOL domains) could be associated with the whole DMN rather than regard each region separately. To our knowledge this is the first study analyzing quality of life and its association with the DMN functional connectivity by using the MDMR approach.

Methods

Participants

The current study did not include volunteers from the general population but instead from a specific sample consisting of female managers. This subsample included 42 female collaborators (age ranging: 30–63, mean 42 years, see Table 2) of the company Natura Innovation/Cosmetics of the state of São Paulo that complained about stress. All participants were right handed and had all a graduation degree as required for their position as managers. All participants signed a consent form and filled in the WHOQOL-BREF, an abbreviated version of the original WHOQOL which assesses the quality of life in four categories (environmental, social, psychological and physiological in the Portuguese version.

Measuring instruments

The World Health Organization quality of life assessment WHOQOL-BREF

The WHOLQOL-BREF (abbreviated version) questionnaire consists of 26 questions examining the quality of life in four domains. This supplies the personal view about the social, environmental, physical and psychological living conditions affecting a person by multiple factors that cannot be objectively analyzed by other medical measurement methods (The Whoqol Group 1998). Each question can be answered on a five-point Likert response scale including the answers: "(1) Not at all", "(2) A little", "(3) A moderate amount", "(4) Very much" and "(5) An extreme amount". The grading of the WHOQOL-BREF is in a positive manner, so that higher scores mean higher quality of life in the measured domain. For each quality of life domain, a mean score was calculated that was later used for MDMR and post-hoc analysis. The time frame of the items is the previous two weeks. In this context it seems that the measurement represents a state rather than a trait assessment of the quality of life. Nonetheless it is important to notice that the setting of specific living conditions and their evaluations can be a long duration process and thus can reflect a trait. A standard reference value for quality of life does not exist for WHOQOL-BREF questionnaire, as the scores differ for each person and are not comparable. Summarized by an international group of collaborators the questionnaire has been shown to reveal a reliable (Cronbach's alpha = 0.701) and valid assessment of subjective quality of life aspects that can be applied across cultures (Skevington et al. 2004). This was further verified for the Portuguese version (Berlim and Fleck 2007).

Image acquisition

Data were acquired using a 3.0 T MR scanner (Tim Trio, Siemens, Erlangen, Germany) with a 32-channel head coil. The resting state acquisition was based on a T2*-weighted echo planar imaging (EPI GRE) for 200 whole brain volumes with the following technical parameters: TR = 2270 ms, TE = 30 ms, slice thickness = 2.7 mm, ga*p* = 0.5 mm, flip angle = 90o, matrix size = 64 × 74, NEX = 1, slices = 40, FoV = 200 mm. A high resolution structural image (MPRAGE) was also acquired for co-registration and normalization procedures (TR = 2500 ms, TE = 3.48 ms, slice thickness = 1 mm, flip angle = 7o, FoV = 256 mm, ma- trix = 256 × 256, NEX = 1).

Image processing

The structural and functional MRI data were preprocessed using the CONN toolbox v.15.g (Whitfield-Gabrieli and Nieto-Castanon 2012). The data were pre- processed by: fMRI realignment and unwarping, structural segmentation (grey matter, white matter and cerebrospinal fluid), registration to the standard space (MNI152 template), functional spatial normalization, motion censoring and spatial smoothing (FWHM = 8 mm). Motion censoring (or "motion scrubbing") is referred to a specific motion correction method that entirely discards problematic data time points that exceed a a-priori determined threshold and functioned as temporal mask. The masked volumes were not included into the GLM estimation what eliminates the influence of corrupted data and decreased the variance in parameter estimates.

For each voxel, band-pass filtering (0.008–0.09 Hz) and nuisance were regressed out using the simultaneous band-pass approach (Hallquist et al. 2013). This includes the simultaneous application of band-pass filtering of fMRI data and nuisance regressors to the same frequency range prior to the regression of the filtered fMRI time series on the filtered regressors. This brings the advantage that noise can be better controlled and the risk to systematically inflate the estimates of functional connectivity is reduced. The nuisance variables were based on white-matter and CSF signals, realignment parameters (Whitfield-Gabrieli and Nieto-Castanon 2012; Hallquist et al. 2013) and motion censoring (discarding volumes with displacement greater than 2 mm and with global-signal z-value greater than 9).

Regions of interest (ROIs)

Regions of interest were set on the basis of the peak foci reported in the article of Fox et al. (2005). The regions were placed on the posterior cingulate cortex (PCC), left and right lateral parietal cortices (LLP), (RLP) and medial pre-frontal cortex (mPFC). The ROIs were spherical with a diameter of 20 mm. As the ROIs were geometrically defined, their spatial limits encopassed different anatomical regions. The lateral parietal regions anatomically include the intraparietal sulcus, the angular gyrus and the supramarginal gyrus. The mPFC also includes the anterior cingulate cortex (ACC) as well as the superior frontal gyrus (midline). The PCC region mainly includes the posterior cingulate cortex and the precuneus. Figure 1 illustrates the four regions of the default mode network used in the study. The exact localization of the peak foci is listed in Table 1.

Multivariate distance based matrix regression (MDMR)

The Multivariate Distance Matrix Regression (MDMR) (McArtor et al. 2017) is a non-parametric method developed to assess the statistical significance of the association between a unidimensional variable and a dissimilarity matrix across subjects. In this study, the unidimensional variable is the phenotypical factor "quality of life", especially its four domains (social, physical, psychological and environmental). The dissimilarity matrix is built by using the functional connectivity among the ROIs for each participant. First applied on high-throughput biological assays in genotype data (Zapala and Schork 2006) the MDMR method is nowadays also used in brain research (Shehzad et al. 2014; Satterthwaite et al. 2015). The advantage for the use of this method for the underlying study was that the behavioral measurements (WHOQOL domains) could be applied to analyze its association with on a

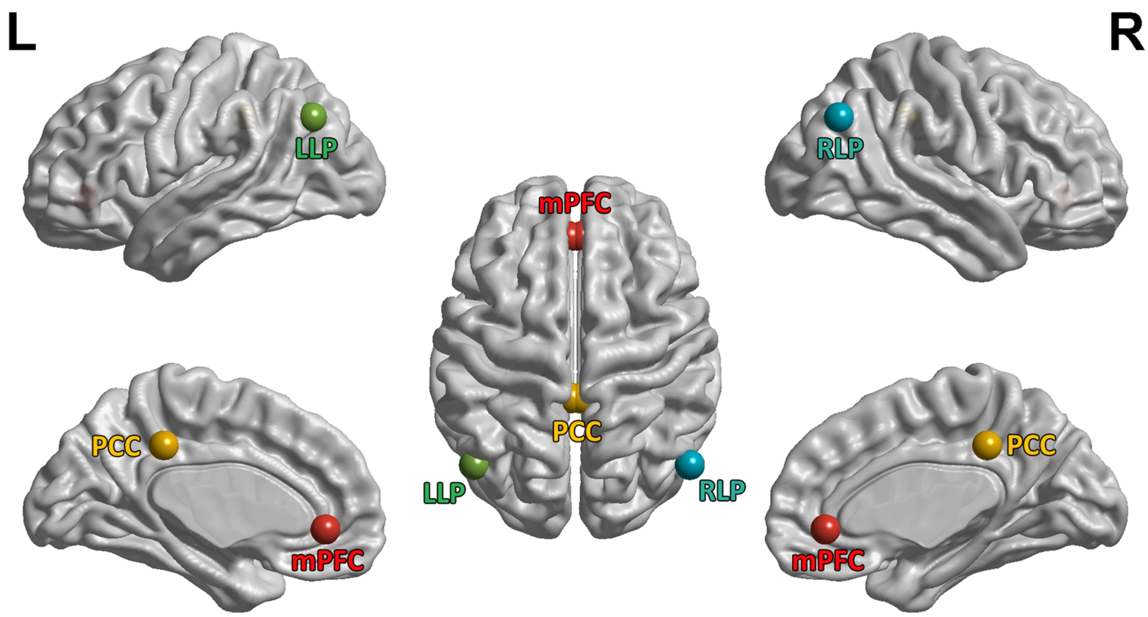

Fig. 1 **Regions of interest** Regions of interest used in the functional connectivity analysis (based on the peak foci of Fox et al. (2005). mPFC = medial prefrontal cortex (red), PCC = posterior cingulate cortex (yel- low), LLP = left lateral parietal cortex (green), RLP = right lateral parietal cortex (blue).The sphere diameter is illustrative, and therefore doesn't correspond to the original ROI size. The figure was created using BrainNet viewer (Version 1.6)

whole network, rather than in previous studies from ROI to ROI or in seed-based approaches (Lanius et al. 2010; Alexopoulos et al. 2012; Luo et al. 2015; McArtor et al. 2017). This not only reduces amount of Bonferroni corrections but also enables to see and understand the function of a whole brain network as a unit and its reaction to influencing factors. MDMR has been shown to have a good level accuracy, a good power and a good flexibility (Zapala and Schork 2012) and was therefore chosen for the analysis. The MDMR analysis was performed using R Version 3.3.0 (2016-05-03) with the MDMR package on an IMac, OS-X version ×86 64-apple-darwin13.4.0 (64- bit). In the first step of the MDMR analysis the preprocessed BOLD extracted time series from each a priori-defined default mode ROI is used to conduct a ROI-to-ROI connectivity analysis by calculating the Spearman's correlation coefficient between each pair of ROIs (Shehzad et al. 2014). In the next step, the multivariate pattern of connectivity for each ROI is compared between subjects using a distance metric (i.e. the dissimilarity matrix) calculated as the square-root of $[2 * (1 - r)]$, which is a function of Spearman's correlation. Following this, the MDMR tests how well each quality of life domain variable (i.e. physical, psychological, social or environmental) explains the distances be- tween each participant's default mode network multivariate connectivity pat- tern. In other words, MDMR provides a measure of how the overall pattern of connectivity of the default mode network is implicated by each group level variable. For each ROI connectivity pattern, MDMR yields a pseudo-F statistic whose significance was assessed using 10,000 iterations of a permutation testing. Resulting p-values were Bonferroni corrected for multiple comparisons considering the number of quality of life domains (i.e. 4) and a rate of false positives of 5%.

Table 1 Names and coordinates of regions of interest in the Talairach space, extracted from Fox et al. (2005)

Name	Talairach coordinates (x y z)
Medial prefrontal cortex (mPFC)	(−3,39,-2)
Posterior cingulate cortex (PCC)	(−2, −36, 37)
Left lateral parietal cortex (LLP)	(−47,-67,36)
Right lateral parietal cortex (RLP)	(53,-67,36)

MDMR post-hoc analysis

As originally stated by Shehzad et al. (2014), MDMR analysis results only allow for the identification of significant associations between a behavioral variable and connectivity patterns of a network. In order to better understand the nature of the effect (i.e., direction and specific connections involved), post-hoc analyses were needed. It was therefore further explored which specific connections of the default mode network might be driven by the associations returned by the MDMR. To do this, the Pearson's correlation between each pairwise correlation of default mode network ROIs (mPFC-PCC; mPFC-LLP; PCC-LLP; mPFC-RLP; PCC-RLP; LLP-RLP) and the significant WHOQOL domain variable returned from the MDMR was calculated. This analysis was conducted using the SPSS software (IBM SPSS Statistics Version 22). Before that, the

Table 2 Sample demographics and questionnaire results

Variables	Mean (SD)*1	Range (Min/Max)
Age (in years)	42.9 (8.5)	33 (30/63)
Social (WHOQOL-BREF)	65.48 (17.42)	66,67 (25/91.67)
Physical (WHOQOL-BREF)	68.23 (13.68)	64.29 (28.57/92.57)
Psychological (WHOQOL-BREF)	66.47 (13.37)	66.66 (29.17/95.83)
Environmental (WHOQOL-BREF)	67.56 (12.40)	46.88 (43.75/90.63)

*1 Mean value and standard deviation

data was checked for normal distribution running a Kolmogorof-Smirnov (KS) test and checking the curtosis and skewness of the data. The KS test for the Social Domain Scores ($p = .116$) and LLP-RLP-Connectivity ($p = .200$) and a visual inspection of their histograms and box-plots showed that these values were approximately normally distributed.

Results

Physiological and behavioral results

Sample characteristics are listed in Table 2 that shows the mean values, standard deviations and ranges that participants achieved in the four main WHOQOL domains.

MDMR analysis

The MDMR analysis revealed a significant association between the social quality of life scores and the functional connectivity of the default mode network. This association survived the Bonferroni-correction for multiple comparisons for four domains, with a value of psocial <0.001. Nevertheless, the psychological domain, that did not survive the Bonferroni correction, showed a significant value of ppsycho = 0.037. The other two domains didn't show a significant association with the functional connectivity of the DMN-regions, with pphysic = 0.231 and penviron = 0.235.

Post-hoc analysis on MDMR results

The correlation analysis revealed a negative correlation between the Social Domain Scores and the LLP-RLP-Correlation ($p = .007$; $r = -.407$, Fig. 2). This indicates that higher social quality of life scores are accompanied by lower connectivity between LLP and RLP regions and vice-versa. All the other pair- wise correlation analyses with the social quality of life domain proved not significant: mPFC-PCC ($p = 0.065$, $r = 0.290$), mPFC-LLP ($r = -0.125$, $p = 0.432$), PCC-LLP ($r = -0.127$, $p = 0.424$), mPFC-RLP ($r = 0.115$, $p = 0.470$), PCC-RLP ($r = 0.103 = p = 0.516$). These associations remained the same after adjusting for the effect of age.

Discussion

The underlying study aimed to investigate whether individual differences in different aspects of quality of life can be represented in differences in the functional connectivity of the DMN. Using a recently elaborated statistical method, the multivariate distance matrix regression (MDMR), we showed that differences in the functional connectivity of the DMN are associated with differences in the evaluation of personal social quality of life. A post-hoc analysis indicated further that this relationship represents probably a negative correlation between social quality of life and the bilateral parietal cortex.

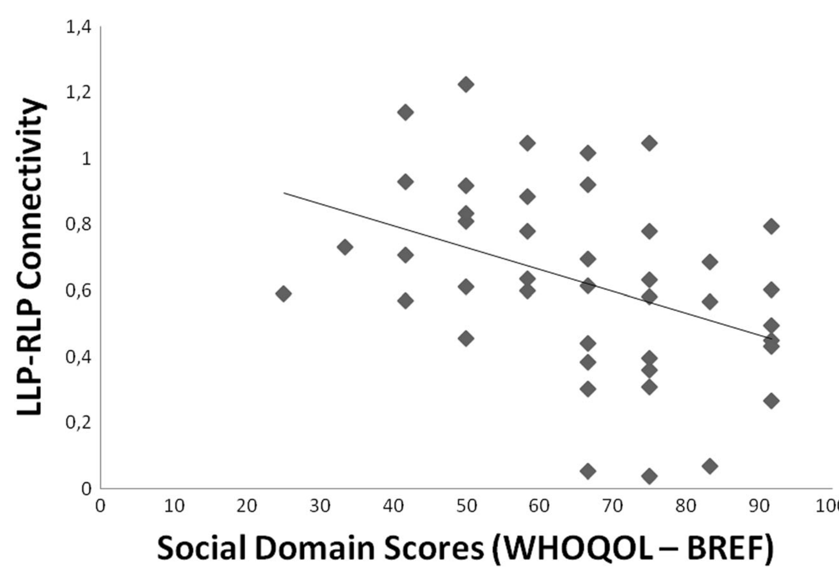

Fig. 2 **Results of the post-hoc analysis** Scatter plot showing the negative correlation of the Social domain scores (WHOQOL-BREF) and the connectivity between the bilateral parietal regions of the DMN (LLP-RLP) ($p = 0.007$; $r = -0.407$). A tendency line was drawn on the basis of least squares methods for a better visualization

A strength of the current study that is worth mentioning is the use of a recently elaborated statistical method for the analysis of the association be- tween the functional connectivity of the DMN and quality of life. The MDMR method can lead to conclusions about the association between the connectivity of a whole network of regions (DMN) and behavioral measurements. Previous studies used seed-based analysis with the computation of seed specific z-statistics and pair wise (partial) correlation approaches in order to test connectivity-behavioral associations (Lanius et al. 2010; Alexopoulos et al. 2012). Other studies used z-values of ICA approaches to show functional connectivity, as z-values represent the contribution of each voxel to all independent components. Afterwards post-hoc correlation analyses were used to find associations between the change of the z value and behavioral measurements (Luo et al. 2016). Nowadays however, to be able to analyze how behavioral measurements are influencing connectome wide associations and whole networks several studies already made use of the MDMR method (Shehzad et al. 2014; Satterthwaite et al. 2015). The advantage in using this method for the underlying study is that the behavioral measurements (WHOQOL domains) could be applied to analyze its association with on a whole network, rather than from ROI to ROI as in previous studies. This not only reduces the risk in computing the alpha error and the amount of Bonferroni corrections but also enables us to see and understand the function of a whole brain network as a unit and its reaction to influencing factors. As far as we know, this study is thus the first one to apply the MDMR method on the DMN functional connectivity.

The findings from the current study are consistent with previous studies relating the DMN with self-referential processes. Literature reveals that DMN resting state activation measurements strongly overlap with self-referential information processing (Northoff and Bermpohl 2004; Beer 2007; Qin and Northoff 2011). The processing of self-related stimuli is largely associated with anterior midline regions and are strongly overlapping with DMN regions. The mPFC and PCC/Pc were shown to be involved in self-referential judgment and evaluation processes (Qin and Northoff 2011). Further literature supports that the DMN is processing cognitive aspects of self-evaluation and supplies updates on the self (Moran et al. 2006).

The significant association between DMN connectivity and the social domain, but not the other domains, are of particular interest. The MDMR analysis showed that the social quality of life domain is associated with the default mode network functional connectivity. The questions related to social quality of life that are considered by the WHOQOL-BREF ask about the satisfaction in relationships to family and friends and the overall sexual satisfaction. A possible explanation for these results may be found in the research about social cognition that indicate an association of the DMN with social life aspects.

Social processing is an important characteristic of humans enabling survival by the establishment of relationships to other persons in a diverse and complex dependency as in no other animal on the planet (Iacoboni et al. 2004). This importance leads to the assumption that thinking about social relationships can be an evolutionary automatic process adapted over years that occurs especially in resting states. Research supporting this finding confirm that the practice of specific cognitive tasks leads to a loss of awareness of the social context (Nakamura and Csikszentmihalyi 2014). Task fMRI social cognition research identify regions of the default mode network activated in a social context (Iacoboni et al. 2004). Several studies analyzing theory of mind (ToM) or mentalizing, situations in that persons have to put themselves in someone else's position (Mar 2011), emphasize the important role of the prefrontal cortex, the temporo-parietal junction (TPJ) and the angular gyrus. Regarding the selected regions of interest in the underlying study that included the angular gyrus, the mPFC and the PCC/Pc, it can be assumed that several regions activated in the DMN are participating in social cognition. Especially considering the results of the post-hoc analysis this association seems plausible. The post-hoc analysis revealed the negative correlation of the bilateral parietal regions (including the angular gyrus) with the social quality of life. Several studies go in line with this finding by showing an overlap between de- fault mode regions and regions activated in autobiographical processing and theory of mind assuming that there is no turn off of the DMN during specific tasks but rather an involvement of its specific regions in these tasks (Wilson et al. 2008; Rabin et al. 2010; Spreng et al. 2009). Self-referential processes in the social context seem thus to play a decisive role in the association of social quality of life and the DMN. Thinking about social relationships in a default mode manner could thus represent our MDMR result.

The post-hoc analysis explored whether we can interpret the MDMR results in a specific direction. The results indicate that there is in particular a negative correlation between the bilateral parietal cortices and the social quality of life, implicating that a low quality in social life is related to a higher functional connectivity between this default mode regions. Questioning what exactly is meant by low quality of life (in terms of the WHOQOL) and its consequences on the human being lead to the fundamental question about satisfaction and happiness. Low self-evaluation of quality of life is probably related to dissatisfaction with social relationships and sex life. Dissatisfaction is a good reason for trouble formation, and troubles subsequently, are an easy catch for the activation of the default mode (Buckner et al. 2008), which could explain the negative correlation discovered in the study. It can be supposed that socially unsatisfied persons are strongly engaged in ruminating past or future situations that they had or will have with surrounding people. The accumulation of dissatisfaction in several areas may result in a lower quality of life, a lower well-being and unhappiness as revealed by previous studies (Killingsworth and Gilbert 2010; Luo et al. 2016). Killingsworth and Gilbert (2010) for example gave the first hint that unhappiness is associated with mind wandering and the stray from actually performed activities. Analyzing 2250 adults using a specific developed mobile application during their daily routines and activities showed not only that people are engaged in mind wandering in 30% of the samples but that, independent of positive or negative thoughts, participants seem to be unhappier when distracting their state from the here and now. Furthermore, thoughts showed to be better in predicting happiness than the activities the subjects were executing. In concluding, the authors suggest that mind wandering, that recruits regions like the DMN, leads to unhappiness that is emotionally ex- pressed as a result (Killingsworth and Gilbert 2010). This finding was then supported by Luo et al. (2014) that compared happy and unhappy people in an fMRI approach. They found altered BOLD signals in the DMN, emotional areas, and the rewarding system of unhappy people. To further explore this issue, they recently conducted a further study concentrating especially on the DMN functional connectivity at rest. Their results indicate that unhappiness and excessive negative self-reflection is associated with increased default mode functional connectivity of the mPFC, PCC and the inferior parietal lobule (IPL) (Luo et al. 2017), Furthermore they found that this increased functional connectivity is positively correlated with the impulse to ruminate. These findings strongly support the results of the current study pointing out the fact that satisfaction is a result of a self-evaluation process and is strongly depending on rumination of experienced events.

Since the ROI's included several regions that were summarized in super- ordinate regions (mPFC, PCC, LLP and RLP) the following study did not consider each region participation in particular but rather regards the DMN as a total network. The findings of the post-hoc analysis showing that the LLP and RLP cortices are negatively associated with social quality of life could however reflect the understanding of the DMN as a combination of several functionally different subdivisions (Lynch et al. 2013). This could explain not only why the DMN regions are differently activated by different cognitive tasks but also that their different task activation should be accompanied by the connection of these regions to different brain areas. As other studies confirm, the resting state is characterized not only by the presence of the DMN but also by the activation of other task positive networks like the dorsal and ventral attention system (Fox et al. 2005), somatomotor system (Biswal et al. 1995), and hippocampal memory systems (Vincent et al. 2006). The heterogeneity in DMN regions associated with different anticorrelated task-positive regions was shown by Lynch et al. (2013). Their finding supports the assumption that the DMN should not be regarded as a uniform single unit, but rather that it consists of several units that are coupled with different anticorrelated areas with which they potentially have inhibitory interactions (Greicius et al. 2003). So, to better understand the function of the DMN it might be important not to consider the DMN as a unit but rather its relation with other networks and regions that are connected to it.

Limitations

The study is limited by the following factors. For the sake of simplicity and considering past default network research, the study chose the core system of the DMN for the MDMR analysis. As the DMN is however connected to other brain regions as well, the analysis could be also further computed for a more expanded set of brain regions or for the whole brain. This should be noted as a starting point for further analyses.

The WHOQOL-BREF questionnaire is assumed to reveal reliable results. Nevertheless, subsequent studies should test other instruments to increase validity. The fact that the post-hoc analysis is based on a predefined set of regions implicates the existence of a"double dipping" or" circularity" (Kriegeskorte et al. 2009; Vul et al. 2009) effect. The post-hoc analysis of the underlying study runs the risk to contain this kind of error. However, as this analysis were used only in order to be able to interpret the direction of the association between social quality of life and the DMN we set no stress on the correlation coefficients in the interpretation of the results. Furthermore we didn't measured sex hormonal levels and didn't consider menstrual cycle of the female participants that could be a potential influence factor with regard to self-evaluation of quality of life. Finally, it should be mentioned that the validity of the results is preliminary, as this is the first study conducting an analysis trying to find an association between quality of life and the brain and therefore requires replication considering other samples.

Conclusion and implications

Our study enabled the opportunity to better understand the effects of quality of life on the brain. The results indicate that quality of life is associated with the functional connectivity of the default mode network. In more detail it can be concluded that social quality of life is negatively associated with the functional connectivity between the bilateral parietal regions of the DMN. Even if the study is concentrated on a non-clinical sample its results can give a hint on the importance in analyzing quality of life in disordered patients that suffer from uncontrollable emotional states. Regulating emotion techniques like meditation stand in contrast to the cognitive reflection about one's own situation that will probably come along with DMN activation (Davidson et al. 2003; Brewer et al. 2011). Meditative techniques could potentially set the basis for an increase of quality of life.

Ethical approval: All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Ethics Committee approval number is CAAE: 38662314.80000.0071.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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