1   **Gender Differences in Like-Sex Middle-Aged Twins: An Extended Network Analysis of**

2   **Depressive Symptoms, Cognitive Functions and Leisure Activities**

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17   **Abstract**

18   **Background:** Depression affects twice as many women as men. Risk factors for depression

19   certainly impact this difference, but their strong interconnectedness challenges the assessment of

20 standalone contributions. Network models allow the identification of systematic independent

21 relationships between individual symptoms and risk factors. This study aimed to evaluate whether

22 the extended networks of depressive symptoms, cognitive functions, and leisure activities in like-

23 sex twins differ depending on gender or zygosity.

24 **Methods:** Twins, including 2,040 women (918 monozygotic and 1,122 dizygotic) and 1,712 men

25 (730 monozygotic and 982 dizygotic), were selected from the Danish Twin Registry for having,

26 along with their like-sex co-twin, completed measures of depressive symptoms, cognition, and

27 leisure activities (physical, intellectual, and social). Networks models were estimated and compared

28 at three levels: co-twins to each other within groups defined by gender and zygosity; monozygotic

29 to dizygotic twins within the same gender, and between genders.

30 **Results:** No significant differences were observed when co-twins were compared to each other,

31 regardless of the pair's zygosity or gender, nor when monozygotic twins were compared to

32 dizygotic twins within gender. However, the gendered networks differed significantly in global

33 strength, structure, and partial correlations between specific depressive symptom and risk factors,

34 all indicating stronger connectedness in women relative to men.

35 **Conclusions:** Environmental factors appear to best explain between-gender network differences.

36 Women's networks showed significantly stronger associations both among depressive symptoms,

37 and between depressive symptoms and risk factors (i.e., decreased cognition and leisure activities).

38 Longitudinal research is needed to determine the causality and directionality of these relationships.

39

40 **Keywords:** gender, network analysis, depressive symptoms, cognitive functions, leisure activities,

41 monozygotic twins

42 **Introduction**

43 Depression, a leading global burden of disease contributor [1] with 20% lifetime prevalence, affects

44 twice as many women as men [2]. An initial epidemiological meta-analysis [3] suggested an

45 absence of gender differences in the heritability for depression, though a recent updated review

46 showed that the behavioural genetics methods used determine whether or not such differences are

47 found [4]. Given the disorder's high heterogeneity, little evidence exists of single genetic or

48 environmental causes explaining all depressive symptoms [5]. Genes certainly contribute to these

49 causes, as monozygotic twins show higher concordance rates for depression diagnosis [3], while

50 environmental factors are critical for triggering its polygenic liability [6,7]; namely the inherited

51 predisposition to develop depression that is conferred by the joined action of several "vulnerability"

52 genes. Besides gene-environment interactions, multiple intertwined aetiologies can explain the

53 gender differences, including hormones, genetically determined physiological stress responsiveness

54 and gender-associated environmental stress exposure [8]. Assessing concurrently these factors to

55 determine their individual contributions is complex; however, it is generally accepted that they are

56 directly expressed in people's cognitive abilities and daily functioning, which in turn are significant

57 predictors of depression [9,10].

58 Cognitive dysfunction is a recognised feature of depression [11], both during an acute episode

59 and following remission [12]. Individuals presenting with depressive symptoms engage less in

60 physical, social and intellectual leisure activities [13], while participation in leisure activities is

61 consistently associated with better cognitive function and a lower risk of cognitive decline [14–18].

62 Moreover, gender differences exist not only in depression prevalence, but also in leisure activity

63 participation and in some cognitive functions. Socially, women tend to establish quicker strong

64 cooperation with others, while men's cooperation levels increase progressively as the activity

65 develops [19]. Women engage less than men in physical activities [20] and face more barriers to

66 exercise [21]. Traditional female-gender role responsibilities, such as childcare and domestic

67 chores, impact negatively on participation in physical exercise, and make prioritising one's health

68   more challenging [22–24]. Gender differences in cognitive function are generally non-significant,

69   with the notable exceptions of women outperforming men in verbal fluency, and men

70   outperforming women in 3D mental rotation [25].

71   Previous studies have rarely explored concomitantly the complex interactions among

72   symptoms, cognitive functions and leisure activities, or evaluated the unique contribution of each

73   depression risk factor independently from its shared associations with other predictors. One study

74   [13] employed structural equation modelling to assess these interrelationships concurrently but

75   aggregated multiple variables into single measures for each of the studied categories. Similarly,

76   another study [26] totalled the performance on five different cognitive domains into a single factor,

77   despite their distinct associations with depressive symptoms. For example, executive function

78   correlates strongly with fatigue, but not with other depressive symptoms (e.g., indecisiveness,

79   appetite changes) [27], while loneliness is associated with memory but not with orientation [28].

80   Reducing distinct phenomena to merged single factors prevents the identification of independent

81   interrelations between specific symptoms and specific risk factors. Moreover, neither study

82   examined the effect of gender on those complex associations, despite known gender differences on

83   most of the studied variables.

84   Conceptualising the interactions between depressive symptoms and risk factors as a network

85   allows to consider each element's individual contribution to the entire system without resorting to

86   the oversimplification of summing up different factors into one. Specifically, when constructing a

87   network where each depressive symptom and risk factor represents a network node, the links

88   (network edges) between each pair of nodes can be studied while accounting for the remaining

89   associations. Traditional models assuming that depressive symptoms are interchangeable

90   representation of a common cause [5], or that cognitive functions stem from a latent single factor

91   are currently challenged [29]. Conversely, network theory allows to analyse the complexity of

92   specific interactions among individual symptoms and various risk factors, revealing patterns and

93   connections that cannot be distinguished with traditional methods [30].

94   Recently, twin data have been modeled using network analyses to explore the heritability of

95   cognitive abilities[29], anxiety [31], and depression [32], but again, known differences between

96   women and men were not considered. We aimed to evaluate the gender effects on extended

97   networks of depressive symptoms, cognitive functions and three types of leisure activities

98   (intellectual, physical and social) using like-sex monozygotic (MZ) and dizygotic (DZ) twin pairs.

99   This method allows, with a strong control for shared genetic liability for depression, to determine

100   the most influential (central) nodes in a network and how symptoms and risk factors may interact to

101   possibly explain the gender differences in depression expression. Two variables known to

102   significantly influence both depressive symptoms and cognitive function – namely, age [33,34] and

103   alcohol consumption [35] – were used as covariates. Specifically, the study first examined the

104   differences between the two members of a twin pair within sub-groups defined by gender and

105   zygosity (i.e., MZ women, DZ women, MZ men, DZ men). Secondly, the differences between MZ

106   and DZ networks were assessed within each gender group. Finally, the extended networks of

107   depressive symptoms of women and men were directly compared.

108

Methods

Study population

111 Participants were collected from two cohort studies of the Danish Twin Registry, the Middle Age

112 Danish Twins (MADT) 2008 survey, and the MIddle Age Danish Twins (MIDT) 2008-2011 survey

113 years [36]. They assessed, respectively, 2,400 and 10,276 Danish twins born between 1931 and

114 1969. Participants self-reported their gender as part of the demographic data collection. Both studies

115 utilised identical measures for depressive symptoms, cognitive functions, and leisure activities [36].

116 The following inclusion criteria were applied: (a) both twins of a pair participated, (b) the pair was

117 like-sex (same gender), and (c) the pair's zygosity was clearly determined.

118

Measures

119 The standardised battery of the MADT and MIDT studies [36] included nine depressive symptoms

120

121 from the Cambridge Mental Disorders of the Elderly Examination [37], six neuropsychological tests

122 to estimate cognitive functions, and a scale measuring the frequency of engagement in three types

123 of leisure activities, eight intellectual, six physical and eight social. Age and alcohol consumption

124 were included as covariates due to their established associations with other variables. See

125 Supplementary Table S1 for all measures' scoring methods and corresponding node names.

126 Descriptive statistics were computed separately for women and men. Categorical variables (e.g.,

127 zygosity, education, marital status, and work status) were analysed using Chi-square tests (χ^2).

128 Independent samples t-tests were conducted to compare between genders for continuous variables.

Network analysis

130 *Network estimation.* Gaussian Graphical Models (GGMs) with graphical Least Absolute Shrinkage

131 and Selection Operator (Glasso) regularisation were used to estimate the undirected networks of the

132 six nodes' categories – 9 depressive symptoms, 6 cognitive functions, 8 intellectual activities, 6

133 physical activities, 8 social activities, and 2 covariates. Glasso was applied with Extended Bayesian

134 Information Criterion (EBIC) for model selection [38]. This method estimates 100 models with

135 varying levels of sparsity. The final model is selected based on the lowest EBIC value, determined

136 by hyperparameter gamma (γ), we set at 0.5 to minimise the risk of including spurious edges. To

137 meet GGM normality requirement, while optimising the original data preservation, nonparanormal

138 transformations were used to normalise variables with absolute skew values >1. Networks were

139 drawn by Cytoscape 3.10.2.

140 *Network centrality.* For each node, centrality measures for strength and expected influence (EI)

141 were calculated with standardised z-scores for each independent network. Strength represents the

142 sum of absolute values of the node's connections to neighboring nodes, while EI refers to the net

143 sum, accounting for positive and negative values [39].

144   *The network stability* was quantified with the correlation stability coefficient (CS-coefficient). It

145   represents the maximum number of cases that can be dropped to retain a centrality correlation of at

146   least 0.7. CS-coefficient values above 0.25 indicate stable networks, although traditionally, values

147   above 0.5 are preferable. Edge accuracy was estimated with bootstrapped 95% confidence intervals

148   (CIs), with narrower CIs suggesting more reliable networks. Bootstrapped difference tests were also

149   performed to evaluate if centrality and edge-weights were stable [38].

150   *The network comparison test (NCT)* with 1000 permutations [40] was used for all between-

151   networks comparisons, using indices of global strength invariance (S) and maximum difference (M)

152   of network invariance. Firstly, differences between co-twin pairs were examined within each of the

153   following sub-groups obtained by crossing gender with zygosity: MZ women, DZ women, MZ men

154   and DZ men. To mitigate randomness due to arbitrary assignment, we reassigned each of these

155   datasets 1,000 times and obtained two averaged networks representing the independent networks of

156   each co-twin [32]. For every reassignment iteration, the NCT evaluated differences in global

157   strength and structure with S and M indices. The 1,000 p-values distribution of each index was used

158   to identify significant differences among the reassignments. Secondly, MZ and DZ networks were

159   compared within each gender group. Finally, overall differences between two genders were

160   assessed.

161

Results

Participants

164   Applying the inclusion criteria to the merged MADT and MIDT databases led to the identification

165   of 1,876 twin pairs (N=3,752), consisting of 2,040 women (918 MZ and 1,122 DZ) and 1,712 men

166   (730 MZ and 982 DZ). Table 1 presents the socio-demographic characteristics of the sample. Figure

167   1 illustrates the three-level sample's subdivisions as required by the network analysis design.

168   _____

169   INSERT TABLE 1 and FIGURE 1 ABOUT HERE

170   _____

171 Network comparisons of co-twins within gender by zygosity sub-groups

172   Networks were constructed and compared between co-twins within each zygosity-gender pair. All

173   networks were stable. After the 1,000 reassignments, the *p*-values for the between-co-twins

174   comparisons did not show any significant differences across all four groups in terms of global

175   strength and network invariance, with all *p*-values >0.94, as shown in Supplementary Table S2. For

176   MZ/DZ women, MZ/DZ men, see Supplementary Figure S1, S7, S13, S19 for networks, Figure S2,

177   S8, S14, S20 for centrality, Figure S3-S6, S9-S12, S15-S18, S20-S24 and Table S3 for stability.

178 Network comparisons of MZ and DZ within each gender

179   After confirming the absence of significant differences between co-twins, sub-groups were merged

180   to compare MZ to DZ networks within each gender, i.e., MZ women vs DZ women and MZ men vs

181   DZ men. All networks were stable. In women, MZ and DZ networks were comparable in both

182   global strength ($S = 1.82$, $p = 0.210$) and structure ($M = 0.11$, $p = 0.483$). Similarly, in men, MZ and

183   DZ networks did not differ significantly neither in global strength ($S = 1.11$, $p = 0.441$), nor in

184   structure ($M = 0.16$, $p = 0.227$), as shown in Supplementary Figure S27, S34 and Table S4. For MZ

185   and DZ in each gender, see Supplementary Figures S25, S32 for networks, S26 and S33 for

186   centrality, S28-S31, S35-S38 and Table S5 for stability.

187 Network comparisons between genders

188   *Networks' stability.* Given the lack of significant zygosity effects, the MZ and DZ samples were

189   further merged to construct two networks for women and men (Figure 2). The networks were highly

190   stable, with CS-coefficients values 0.75 (see Supplementary Figure S39-S42 and Table S6).

191   _____

192   INSERT Figure 2 ABOUT HERE

193   _____

194   *Nodes' centrality and edges.* See full results in Supplementary Figure S43 and Tables S7-S10. The

195   gendered networks showed similar patterns in nodes' centrality which reflects the importance of

196   nodes (Supplementary Figure S43). For both, the same depressive symptoms, *Sad* (strength$_{women}$ =

197   1.08, EI$_{women}$ = 1.03; strength$_{men}$ = 1.08, EI$_{men}$ = 1.07) and *HappyNow* (strength$_{women}$ = 1.03, EI$_{women}$

198   = 0.86; strength$_{men}$ = 0.92, EI$_{men}$ = 0.79), and the same physical activity *Exercised* (strength$_{women}$ =

199   1.05, EI$_{women}$ = 0.86; strength$_{men}$ = 1.02, EI$_{men}$ = 0.97), were among the top 5 most influential nodes.

200   The latter also included intellectual leisure activities, that was going to the *Museum* (strength =

201   1.01; EI = 1.01) for women, or to the *Library* (strength = 0.99; EI = 0.81), and to *Courses* (strength

202   = 0.96; EI = 0.94) for men. The most central cognitive function was *DelayedRecall* (strength =

203   1.04; EI = 0.64) for women and *WorkingMemory* (strength = 0.86; EI = 0.83) for men.

204   The two genders showed similar edges with the top 5 absolute partial correlation values.

205   These concerned cognitive functions – *Learning-DelayedRecall* (pr_{women} = 0.55; pr_{men} = 0.45),

206   *WorkMemo-AuditAtt* (pr_{women} = 0.33; pr_{men} = 0.30), social activities – *MeetTwin-PhoneTwin*

207   (pr_{women} = 0.53; pr_{men} = 0.54), *Dinner-FriendsDinner* (pr_{women} = 0.33; pr_{men} = 0.35), and physical

208   leisure activities, where the edge with the highest value was *Yoga-Exercised* for women (pr = 0.33),

209   and *Sport-Exercised* for men (pr =0.42). All these correlations were positive, indicating strong

210   connectivity within the corresponding risk factor's individual nodes.

211   *NCT*. Figure 3 showed that the gendered networks were significantly different in both global

212   strength (S = 1.87, p = 0.022) and structure (M = 0.14, p = 0.009). Table 2 lists all nodes with

213   significantly different between-gender centrality values. All indicated stronger connectivity of the

214   corresponding nodes in women.

215   _____

216   INSERT FIGURE 3 AND TABLE 2 ABOUT HERE

217   _____

218   When examining the edges connecting depressive symptoms with the remaining network

219   nodes, 10 were found to be significant in women and only one in men. Table 3 details all edges

220   involving depressive symptoms with significant between-gender differences. Non-significant edges

221   within each gendered network are listed in Supplementary Tables S11-S12. Figures 1c and 1d

222   visualise the gendered sub-networks centred with depressive symptoms and related risk factors to

223   better illustrate where the core differences between women and men were concentrated. Two of

224   these edges with significant differences concerned positive correlations between depressive

225   symptoms. Specifically, women showed significantly stronger associations for *Lonely-*

226   *WorthNothing* ($pr_{women} = 0.151$, $pr_{men} = 0.065$; $p = 0.030$) and for *Tense-Outlook* ($pr_{women} = 0.118$,

227    $pr_{men} = 0.019$; $p = 0.009$). The remaining results concerned significantly stronger negative edges

228   linking depressive symptoms with either cognitive functions or leisure activities. The only

229   exception was the positive association *WriteStory-HappyNow*. Except Outlook-Courses, all these

230   edges linking depressive symptoms with risk factors were null in men.

231   _____

232   INSERT Table 3 ABOUT HERE

233   _____

234

Discussion

236   The study aimed to evaluate gender differences within and between like-sex co-twins. The observed

237   networks were stable and without significant differences when co-twins were compared to each

238   other, regardless of the pair's zygosity or gender. Given these similarities, samples were pooled so

239   to compare MZ to DZ women, and MZ to DZ men, leading to non-significantly different networks.

240   However, when comparing the gendered networks (all women vs all men), significant differences in

241   global strength, global structure and local structure emerged. Specifically, women's networks were

242   denser (more interconnected) and showed significantly stronger associations both within depressive

243   symptoms, and between depressive symptoms and risk factors (i.e., cognition and leisure activities).

244   Traditional models compare MZ and DZ twins to determine the relative contribution of genetic and

245   environmental factors to the observed differences in variances/covariance within twin pairs [41].

246   Similarly, the network comparison test evaluates the overall differences in interconnectivity

247   between co-twins first, and between MZ and DZ twins second, in order to examine these

248   contributions at the network level [32]. Previous research using network analyses in MZ and DZ

249   twins has not considered gender effects [29,31,32] and focused on within-symptoms [31] or with-

250   cognitive functions [42] analyses. Overall, our results suggest that between-gender differences in

251   the extended networks of depressive symptoms and the studied risk factors may be predominantly

252   environmentally determined.

253   The gendered networks' comparison revealed several significant differences. Among

254   depressive symptoms, worthlessness and subjective tension were more central in women. Edges

255   *worthlessness-loneliness* and *pessimistic outlook - subjective tension* were stronger in women.

256   These results are consistent with both the established higher prevalence of depressive symptoms in

257   women [2,8] and the network theory of psychopathology, postulating that more densely connected

258   symptom networks are associated with a stronger predisposition to depression [30].

259   Moreover, the women's networks showed significantly stronger negative associations

260   between depressive symptoms and physical or social leisure activities, including *worthlessness -*

261   *frequency of calling family/friends*, *worthlessness - frequency of visiting family/friends for dinner*,

262   and *subjective tension - strenuous sports engagement*. Subjective tension often indicates anxiety,

263   which is closely related to a pessimistic view of the future [43]. This relationship is further

264   evidenced by women being more likely to engage in rumination, a cognitive process that can

265   perpetuate negative thinking and hinder the ability to maintain a positive outlook [43]. Socialisation

266   and cultural expectations play a significant role in shaping how genders perceive their futures.

267   Women are often socialised to prioritise the quality of relationships and emotional connectedness,

268   which, can lead to feelings of worthlessness and pessimism regarding future outlook [44]. This is

269   further supported by the higher links' strength of *worthlessness-loneliness*, *frequency of feeling*

270   *happy - frequency of calling family/friends*, and *sadness-associations* in women relative to men.

271   Research indicates that women exhibit greater emotional awareness and regulation skills, which can

272   lead to a more nuanced view of their social world and own future [45]. However, this emotional

273   intelligence may also result in heightened sensitivity to relationships' quality and life's

274   uncertainties, potentially contributing to a more pessimistic outlook [45]. Social and cultural

275   factors, including stereotyped expectations, could also underlie the stronger association between

276   *subjective tension-strenuous sports engagement* in women. Body image concerns and traditional

277   female domestic responsibilities can increase tension and impede physical activity prioritisation

278   [21], while the latter can prevent tension release.

279   Other connections linking depressive symptoms and leisure activities that showed

280   significantly stronger, negative correlations in women relative to the absence of such correlations

281   (zero values) in men, involved *pessimistic outlook - frequency of biking*, and *current unhappiness*,

282   with intellectual activities. Regardless of gender, depression is linked to lower participation in

283   physical and other leisure activities [13]. Moreover, women and men differ in how much they

284   engage in physical activities, with women reporting more obstacles to exercising and less control

285   over their exercise choices [21]. Interestingly the only association that was significantly stronger in

286   men concerned higher pessimistic outlook with lower engagement with courses. These results

287   suggest that engaging in physical, intellectual, or social activities may be associated with fewer

288   depressive symptoms, especially in women. However, our cross-sectional design precludes

289   determining if this engagement directly intervenes upon reducing depression. Nevertheless, the

290   value of participation in leisure activities relative to depressive symptoms appears particularly

291   relevant for women. Studies suggest that women may derive greater emotional and psychological

292   benefits from social interactions and recreational activities, which could be due to the relational

293   nature of women's socialisation [46]. Gender differences in coping strategies also shape how

294   individuals respond to stressors. Research indicates that women are more likely to engage in

295 emotion-focused coping strategies, including seeking social support and participating in activities

296 that promote emotional well-being [46]. This difference in coping styles might explain the reasons

297 behind the stronger associations between leisure activities' engagement and depressive symptoms in

298 women relative to men.

299   Within both women's and men's networks, cognitive functions ranked among the most

300 central elements and were strongly interconnected. However, few between-genders differences

301 involved cognition. Specifically, *delayed verbal memory* was more central in women, whereas

302 *pessimistic outlook* was more strongly connected negatively to both *delayed verbal memory* and

303 *verbal fluency* in women. The associations between depressive symptoms and cognitive functions

304 are known to be bidirectional [47], but in midlife, cognition does not predict future depressive

305 symptoms, while depressive symptoms do predict lower future cognitive function, concerning

306 especially memory [47,48]. Moreover, longitudinal research indicates that baseline memory is not

307 associated with depression at follow-up in women aged over 65 [48]. Thus, our results may suggest,

308 in women, a pessimistic outlook could be the key bridge node through which depressive symptoms

309 exercise their deleterious effect over long-term memory. However, this hypothesis needs to be

310 verified by longitudinal research. Importantly, leisure activities appear overall more central to the

311 extended networks of depressive symptoms than cognitive functions. Withdrawal from leisure

312 activities is well-documented in depressed individuals [49]. Despite being cross-sectional, our

313 findings allow to speculate that this association may emerge prior to a depression diagnosis, and be

314 more prominent in women, supporting the hypothesis that intellectual, physical, and social leisure

315 activities may serve as protective factors against depression [49,50]. Nevertheless, future

316 longitudinal studies are necessary to determine if such causal relationships exist.

317   The study has the following limitations. As research participants were middle-aged Danish

318 twins, results are not necessarily generalisable to other ethnicities, age-groups, or broader

319 populations. Moreover, contemporaneous networks based on GGMs do not possess causal inference

320 capabilities. Therefore, significant associations should be interpreted with caution. The *HardWork*

321   item primarily referred to family/work hard physical duties rather than leisure; nonetheless, we have

322   retained it within the physical activities' category to determine overall physical engagement. This

323   inclusion did not significantly affect the results, as *HardWork* remained in the periphery of all

324   networks. In future research, methodology such as longitudinal network analysis coupled with

325   Bayesian network reasoning could be used to evaluate the directionality in observed significant

326   edges, and thus further clarify gender differences. Our study did not evaluate the specific genetic,

327   shared and nonshared environmental portions of the studied variables' variance. Future research

328   could therefore apply traditional twin-design structural equation modelling (SEM) [41], alongside

329   the network analyses, to determine the exact genetic and environmental contributions to the

330   observed results. Our study did not include an assessment of lifestyle factors, which encompass a

331   broad range of daily behaviours, such as smoking, substance consumption, and nutritional intake

332   [51, 52]. Both leisure and lifestyle factors represent essential aspects of daily life, and can act as risk

333   factors for depression. Network models of the relationship between lifestyle factors and depression

334   have already been studied [51–53]. Future research should integrate both lifestyle factors and

335   leisure activities for a more thorough assessment of their combined impact on depression.

336   Combining network analyses with a twin design enables the evaluation of the independent

337   associations between depressive symptoms and risk factors, and the study of how gender may affect

338   these relationships. This approach contributes towards current intervention science efforts towards

339   the identification of the diverse mechanisms leading to depression, and the associated personalised

340   targets for prevention [54]. Although the present novel findings require replication in other

341   representative samples, they do indicate that personalised prevention should take gender into

342   consideration and integrate the promotion of relevant leisure activities.

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Conflict of interest

Both authors report no financial relationships with commercial interests.

Data availability

In compliance with Danish and EU regulations, the transfer and dissemination of individual-level data from Danish registries require prior authorization from the Danish Data Protection Agency. Current local data protection policies prohibit the sharing of individual-level data in public databases. Data request can be directed through https://www.sdu.dk/en/forskning/dtr.

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525

526 **FIGURE 1. Diagram of the network comparisons conducted at three levels of analysis: (1)**

527 **between co-twins of the same zygosity, (2) between zygosity types, and (3) between genders.**

528
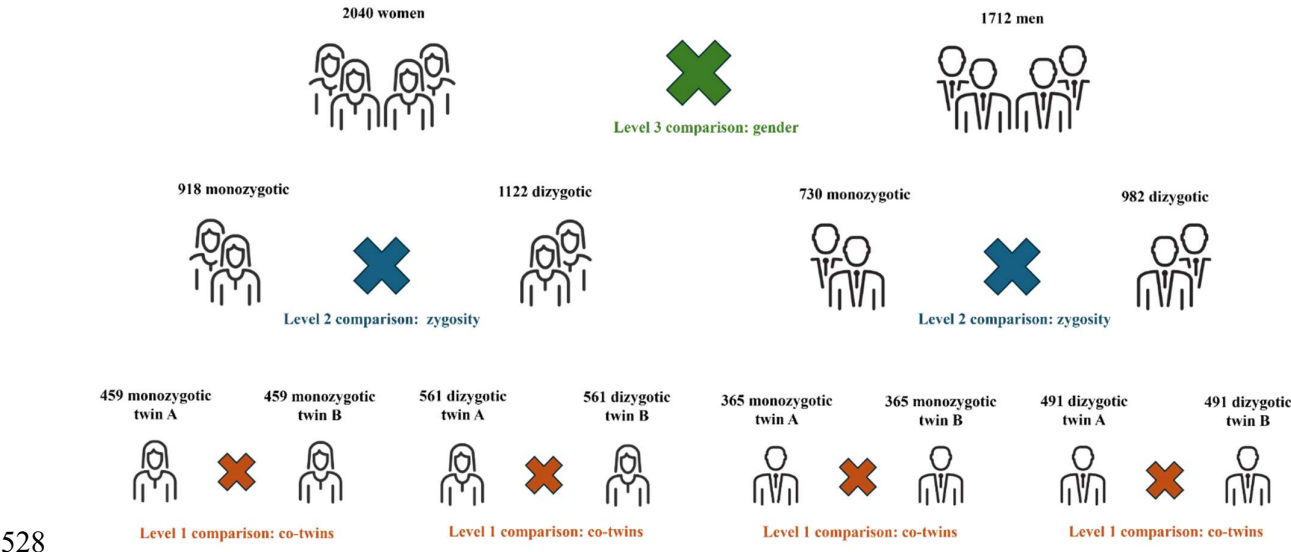
529

530 **FIGURE 2. Women's and men's GGM networks of depressive symptoms, cognitive functions,**

531 **frequency of leisure activities and covariates.**
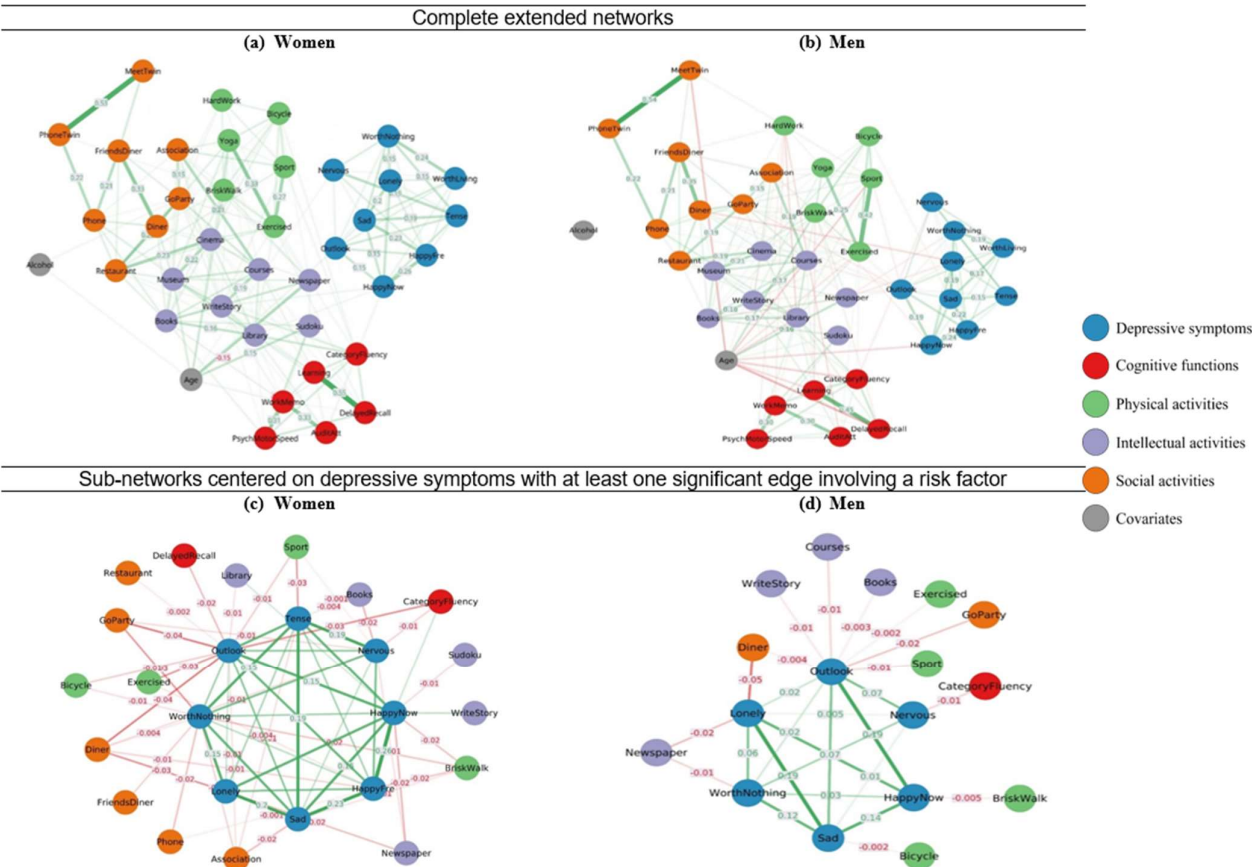
533 Green lines represent positive partial correlations, and red lines represent negative partial

534 correlations.

535

FIGURE 3. The network comparison test's distribution of the 1000 permutations of global strength and maximum difference indices in women and men. The red marker indicates the observed test statistic within the permutation test, highlighting its position to assess statistical significance.
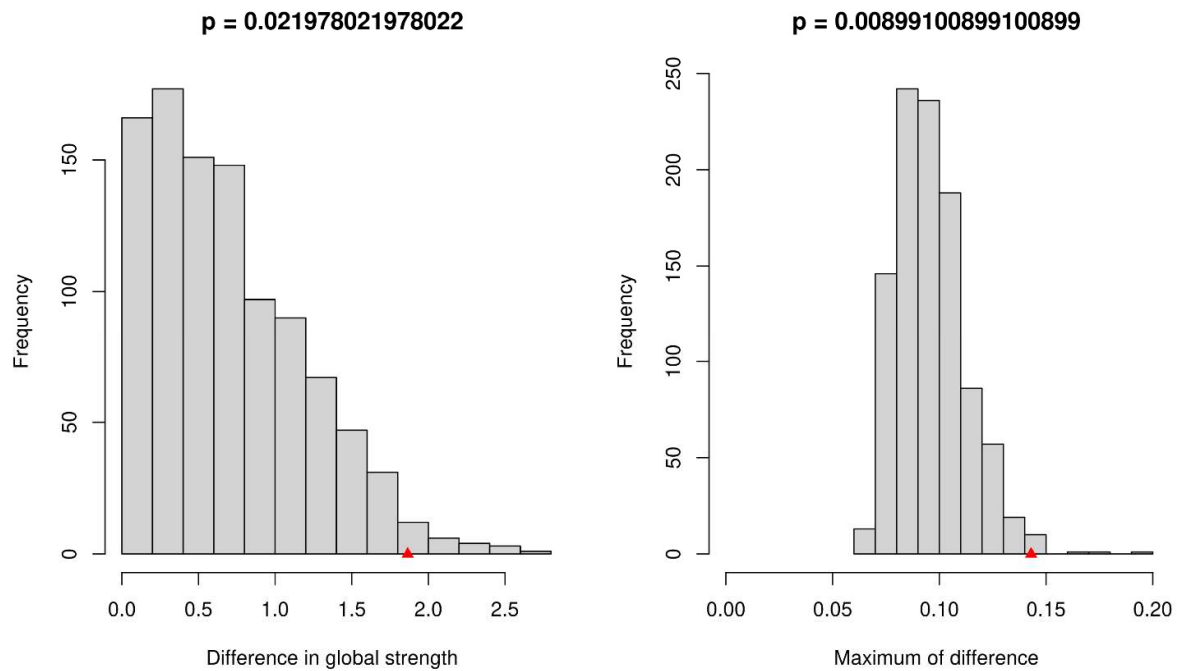
543 **TABLE 1. Descriptive statistics of the sample and between-gender differences**

Variable	Women (n=2040)		Men (n=1712)		Statistic[a]	p-value
Zygosity					$\chi 2\ (1) = 2.01$	0.294
MZ	918		730			
DZ	1122		982			
Education					$\chi 2\ (6) = 117.00$	0.000***
Master	139		209			
Bachelor	600		340			
Tertiary	88		77			
Post-secondary non-tertiary	119		35			
Upper secondary	566		609			
Lower secondary	283		212			
Missing values	245		230			
Marital status					$\chi 2\ (5) = 55.42$	0.000***
Married/cohabitating	1533		1430			
Divorce	220		118			
Separated	33		15			
Widow	125		43			
Never been married/cohabitating	116		93			
Missing values	13		13			
Work status					$\chi 2\ (7) = 218.04$	0.000***
Full-time	849		1012			
Part-time	379		90			
Early retired	167		108			
Retired because of special reasons	112		48			
Retired	376		349			
Sick for >14 days	31		13			
Other	101		78			
Missing values	25		14			
	Mean	**SD**	**Mean**	**SD**	**t (3750)**	**p-value**
Age[b]	56.76	9.84	59.24	9.55	-7.81	0.000***
	Mean	**SD**	**Mean**	**SD**	**t (3750)**	**p-value**
Units of weekly alcohol consumption	5.45	5.76	10.73	9.98	-20.07	0.000***
Depressive symptoms	**Mean**	**SD**	**Mean**	**SD**	**t[a] (3750)**	**p-value**
HappyNow [c]	1.12	0.33	1.10	0.31	1.73	0.000***
HappyFre [c]	1.23	0.45	1.16	0.40	4.69	0.084
Lonely	1.39	0.55	1.24	0.45	8.50	0.000***
Tense	1.23	0.45	1.14	0.37	6.28	0.000***
Nervous	1.09	0.29	1.05	0.22	4.89	0.000***

	Mean	SD	Mean	SD	t^a (3750)	p-value
Sad	1.16	0.39	1.07	0.25	7.99	0.000***
WorthNothing	1.28	0.49	1.25	0.46	1.89	0.000***
Outlook	3.15	1.22	2.90	1.35	4.80	0.0582
WorthLiving	1.06	0.23	1.03	0.18	3.22	0.001**
Cognitive functions	**Mean**	**SD**	**Mean**	**SD**	t^a **(3750)**	**p-value**
Learning	6.37	1.68	5.64	1.55	12.19	0.000***
AuditAtt	5.64	1.20	5.72	1.30	-1.89	0.059
WorkMemo	4.39	1.32	4.49	1.47	-1.73	0.083
CategoryFluency	24.84	6.34	23.76	6.27	3.50	0.000***
DelayedRecall	6.36	2.43	5.01	2.15	16.10	0.000***
PsychMotorSpeed	30.55	10.25	30.11	11.54	2.66	0.008**
Intellectual activities	**Mean**	**SD**	**Mean**	**SD**	t^a **(3750)**	**p-value**
Museum	1.98	0.53	1.96	0.54	2.75	0.006**
Library	3.65	1.16	3.77	1.24	-4.66	0.000***
Sudoku	2.94	1.39	2.40	1.41	13.10	0.000***
Books	3.72	1.15	3.48	1.15	6.82	0.000***
Courses	2.13	0.70	2.02	0.67	4.70	0.000***
WriteStory	1.93	1.16	1.86	1.17	1.49	0.136
Cinema	2.15	0.51	2.06	0.50	4.69	0.000***
Newspaper	4.40	0.88	4.59	0.74	-4.85	0.000***
Physical activities	**Mean**	**SD**	**Mean**	**SD**	t^a **(3750)**	**p-value**
Exercised	3.15	1.22	2.90	1.35	4.80	0.000***
BriskWalk	3.42	1.13	3.05	1.24	11.13	0.000***
Bicycle	2.98	1.31	2.94	1.28	0.88	0.379
Yoga	2.68	1.36	2.17	1.37	11.61	0.000***
HardWork	2.91	1.23	3.11	1.18	-5.28	0.000***
Sport	1.96	1.21	2.13	1.27	-5.45	0.000***
Social activities	**Mean**	**SD**	**Mean**	**SD**	t^a **(3750)**	**p-value**
GoParty	2.70	0.66	2.65	0.64	2.01	0.044*
Restaurant	2.44	0.60	2.36	0.56	3.58	0.000***
Phone	4.18	0.68	3.86	0.77	12.98	0.000***
Diner	2.62	0.60	2.50	0.60	6.40	0.000***
FriendsDiner	2.89	0.65	2.77	0.65	5.52	0.000***
Association	2.32	0.92	2.49	0.97	-5.48	0.000***
MeetTwin	4.75	0.92	4.55	0.96	5.46	0.000***
PhoneTwin	5.47	1.04	4.78	1.11	18.72	0.000***

544 *Note.* [a] controlled for age and alcohol consumption

545   [b] Age range: women, 40.28-79.53; men, 40.29-79.93

546   [c] Reverse coded

547   *p* < 0.05, **p* < 0.01, ***p* < 0.001.

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549

550 **TABLE 2. Nodes with significant differences in strength centrality between women and men**

Strength	Women	Men	*p*-value	Node category
WorthNothing	0.9465153	0.6203046	0.009**	Depressive symptom
Tense	0.8696782	0.6016601	0.009**	Depressive symptom
Yoga	0.7413204	0.4734702	0.003**	Physical activity
Museum	1.0094376	0.7608950	0.012*	Intellectual activity
Newspaper	0.6299685	0.3673111	0.007**	Intellectual activity
Restaurant	0.9653388	0.7509232	0.004**	Social activity
DelayedRecall	1.0370145	0.7964581	0.002**	Cognitive function

551 Note. *p < 0.05, **p < 0.01, ***p < 0.001

552

553

554   **TABLE 3. Between-gender comparisons on edges with significant differences involving at**

555   **least one depressive symptom**

Edge	*pr* women	*pr* men	*p*-value	Category of the second node
Lonely-WorthNothing	0.1506603	0.0648693	0.030*	Depressive symptom
Tense-Outlook	0.1180386	0.0194005	0.009**	Depressive symptom
Outlook-Courses	0.0000000	-0.0124933	0.034*	Intellectual activities
HappyNow-WriteStory	0.0251031	0.0000000	0.009**	Intellectual activities
Outlook-Bicycle	-0.0139321	0.0000000	0.046*	Physical activities
Tense-Sport	-0.0285701	0.0000000	0.002**	Physical activities
HappyNow-Sudoku	-0.0074014	0.0000000	0.002**	Intellectual activities
HappyNow-Newspaper	-0.0221540	0.0000000	0.013*	Intellectual activities
HappyFre-Phone	-0.0009168	0.0000000	0.017*	Social activities
WorthNothing-Phone	-0.0170763	0.0000000	0.000***	Social activities
WorthNothing-FriendsDiner	-0.0111974	0.0000000	0.034*	Social activities
Sad-Association	-0.0185778	0.0000000	0.024*	Social activities
Outlook-CategoryFluency	-0.0336071	0.0000000	0.034*	Cognitive functions
Outlook-DelayedRecall	-0.0183782	0.0000000	0.016*	Cognitive functions

556   *Note.* **pr**, partial correlation
557   *p < 0.05, **p < 0.01, ***p < 0.001.
558

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560