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Loneliness is Negatively Related to Facebook Network Size, but Not Related to Facebook Network Structure

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Abstract

High levels of loneliness are associated with poorer outcomes for physical and mental health and a large body of research has examined how using social media sites such as Facebook is associated with loneliness. Time spent on Facebook tends to be associated with higher levels of loneliness, whereas a larger number of Facebook Friends and more active use of Facebook tends to be associated with lower levels of loneliness. However, whilst the network size and structure of 'offline' networks have been associated with loneliness, how the network structure on Facebook is associated with loneliness is still unclear. In this study, participants used the Getnet app to directly extract information on network size (number of Facebook Friends), density, number of clusters in the network, and average path length from their Facebook networks, and completed the 20-item UCLA Loneliness questionnaire. In total, 107 participants (36 men, 71 women, $M_{age} = 20.6$, $SD_{age} = 2.7$) took part in the study. Participants with a larger network size reported significantly lower feelings of loneliness. In contrast, network density, number of clusters, and average path length were not significantly related to loneliness. These results suggest that whilst having a larger Facebook network is related to feelings of social connection to others, the structure of the Facebook network may be a less important determinant of loneliness than other factors such as active or passive use of Facebook and individual characteristics of Facebook users.

Keywords: Social network structure; Facebook; loneliness; social network size; social network

Introduction

Loneliness is defined as the distressing feeling arising from the mismatch between the quantity and quality of social relationships we have and those we want (Perlman & Peplau, 1981), and high levels of loneliness are associated with poorer outcomes for both physical and mental health. Several meta-analyses have found that loneliness is associated with an increased risk of mortality (Holt-Lunstad et al., 2010; Holt-Lunstad et al., 2015; Rico-Urbe et al., 2018), whilst high levels of loneliness are also associated with depression (Erzen & Çikrikci, 2018; Richardson et al., 2017), and - in old age - cognitive decline (Hawkey & Cacioppo, 2010) and dementia (Lara et al., 2019). Whilst loneliness can be found across all age groups, a large, international study ($n = 46,054$, 237 countries, aged 16–99) found that loneliness is negatively correlated with age, with levels of loneliness higher in younger people (Barreto et al., 2021). Other studies have found non-linear associations with age, with large nationally representative surveys from Germany (Luhmann & Hawkey, 2016), Denmark (Lasgaard et al., 2016) and the UK (Victor & Yang, 2012) reporting higher levels of loneliness in young adults (aged 16–30 years-old) and older adults (over 75 years-old).

Given the serious consequences of loneliness (Erzen & Çikrikci, 2018; Hawkley & Cacioppo, 2010; Holt-Lunstad et al., 2015; Rico-Urbe et al., 2018), there has been much debate about the underlying causes of loneliness and whether levels of loneliness are increasing (Dahlberg et al., 2018; Fischer, 2009; Hampton & Wellman, 2018; McPherson et al., 2006; Putnam, 2000). In particular, given the rise in the use of social networking sites (SNSs) over the last two decades, there has been a large body of research focused on the association between the use of SNSs and levels of loneliness (Frison & Eggermont, 2020; Nowland et al., 2018; Seabrook et al., 2016; Song et al., 2014).

Facebook is the most widely used SNS globally, with 2.6 billion monthly active users in April 2020 (<https://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/>). Therefore, much of the research on the use of SNSs and loneliness has focused on Facebook users. Given that SNSs are designed to foster social connections between people, and loneliness is associated with perceived social isolation (Hawkley & Cacioppo, 2010; Nowland et al., 2018), it may be expected that greater use of SNSs would always be associated with lower feelings of loneliness. However, the research findings in this area have been mixed, with the effect of SNSs use on loneliness dependent on factors such as the type of Facebook use, motivations for Facebook use and the individual characteristics of the user (Berezan et al., 2020; Frison & Eggermont, 2020; Nowland et al., 2018; Seabrook et al., 2016; Song et al., 2014). A meta-analysis of research on Facebook use and loneliness found that frequent users of Facebook were lonelier and suggested that this may be accounted for by lonely people using Facebook more, rather than Facebook use itself making people feel lonelier (Song et al., 2014). In terms of type of use, active use of SNSs (direct exchanges of communication with others) tends to be associated with lower levels of loneliness, whereas passive use of SNSs (scrolling through newsfeeds) is associated with higher levels of loneliness (Burke et al., 2011; Burke & Kraut, 2016; Frison & Eggermont, 2020; Lin et al., 2020; Verduyn et al., 2015). This is supported by experimental work showing that an increase in posting on Facebook over a period of one week was associated with lower feelings of loneliness (Deters & Mehl, 2013). More recent longitudinal research has suggested a curvilinear relationship between active Facebook use and loneliness in adolescents, with active Facebook use associated with decreased social and emotional loneliness among those with low to moderate SNSs use (Wang et al., 2018). However, for those with high levels of Facebook use, increased active use of Facebook was associated with higher levels of loneliness.

In addition to the amount and type of SNSs use, another important SNSs factor that may be related to loneliness is the size and structure of the network of Facebook Friends users have (a capital F is used when referring to Facebook friends, to distinguish them from friends in the broader sense). Almost all research in this area has focused on the size of the network – the number of Facebook Friends – and most research has found that users with a larger number of Facebook Friends feel less lonely (Greitemeyer et al., 2014; Lemieux et al., 2013; Nowland et al., 2018; Phu & Gow, 2019; Song et al., 2014). However, some studies have found those with more Friends feel lonelier (Skues et al., 2012), whilst other research has found a curvilinear effect, with loneliness decreasing as the number of Facebook Friends increased but then increasing again in participants with large numbers of Friends (Wohn & LaRose, 2014). Overall, a large Facebook Friends network may increase the opportunities to establish social ties and to feel socially connected to others (Berezan et al., 2020; Burke et al., 2011; Burke & Kraut, 2016; Song et al., 2014; Yang & Lee, 2020).

However, little is known about how the structural aspects of Facebook or other SNSs networks are related to loneliness. These structural aspects relate to the pattern of connections between a user's Facebook Friends, and there is some evidence that these aspects may be important in explaining the associations between SNS use and well-being. For example, Homan et al. (2014) examined an online LGBTQ (lesbian, gay, bisexual, transgender and queer) support SNS, Trevor Space, focusing on how the network structure of the users was related to self-reported depressive symptoms. Individuals low in depression were more tightly integrated into the online network than those higher in depression, suggesting that online network structure may influence, or reflect, psychological well-being. Whilst a review called for a focus on how SNSs network structure is related to well-being (Seabrook et al., 2016), and there has been research on how structural aspects of Facebook networks are related to perceived social capital (Brooks et al., 2014), to the best of our knowledge there have been no studies examining how the structure of Facebook networks is related to loneliness.

Given the lack of research on the association between SNSs network structure and loneliness, we partly draw on the extensive literature of 'offline' social networks and loneliness to identify important aspects of network structure and how they may be associated to loneliness in Facebook users. With increasing offline *network size*,

people are less likely to experience loneliness, as they have a greater number of social resources to draw upon and lower levels of perceived social isolation (Binder et al., 2012; Cacioppo et al., 2009; Hawkey et al., 2008). *Density* is the proportion of ties present in the network, relative to all possible ties and varies between zero and one (Bell, 1991). Thus, for a given network, if all the people in that network are connected with everyone else in the network (e.g., they are all friends with each other), then the density of the network will be one. For a specific Facebook user, a dense network will be one in which all of their Friends know each other. A high interconnectedness of individuals within a network may make the network more cohesive and more effective at providing social support, and is associated with lower feelings of loneliness in offline networks (Bell, 1991; Stokes, 1985).

In addition to size and density, another important property of social networks is the number of clusters, defined as sub-groups of the network that are more closely connected to each other than the rest of the network (Friggeri et al., 2011). Facebook networks consist of a number of different clusters, typically representing groups of closely connected Friends from different contexts (e.g., family, school, University, work, interest groups (Binder et al., 2009; Brooks et al., 2014; Friggeri et al., 2011; Lewis et al., 2008). The number of clusters in the Facebook network might influence loneliness, as in offline networks being a member of a cohesive group increases the chance to develop friendships and to profit from feelings of belonging (Brooks et al., 2014; Hawkey et al., 2008). Finally, the *average path length* of a network is the average shortest path connecting two people in the network (Golbeck, 2013) and is used as a measure for the efficiency of information transfer within a network (Myers et al., 2014; Onnela, 2007; Watts & Strogatz, 1998). Average path length relates to the 'small world phenomenon', which examines the minimum number of intermediate people which would be required to link two people drawn at random from the population (Travers & Milgram, 1969; Watts & Strogatz, 1998). For the Facebook networks of our participants, if Sophia is Friends with John, and John is Friends with Leo, then the path length between Sophia and Leo is two, as there are two 'steps' between Sophia and Leo: Sophia to John, then John to Leo. A small average path length in a network can increase sharing of information which in turn contributes to feelings of belonging and trust (Mesmer-Magnus & DeChurch, 2009), concepts associated with lower levels of loneliness (Hawkey et al., 2008; Rotenberg, 1994). Overall, therefore, different structural aspects of offline networks are strongly associated with loneliness, with networks in which individuals have a greater degree of interconnectedness with network members associated with lower levels of loneliness. Given the importance of SNSs in building and maintaining social relationships (Berezan et al., 2020; Burke et al., 2011; Burke & Kraut, 2016; Ellison et al., 2014; Yang & Lee, 2020), and the influence of structural aspects of Facebook networks on perceived social capital (Brooks et al., 2014), it may be expected that structural aspects of Facebook networks would be related to loneliness.

In this paper, we extend the work on SNSs use and loneliness in two key ways. First, in addition to examining how the size of SNSs networks are associated with loneliness as in previous research (Burke & Kraut, 2016; Song et al., 2014; Teppers et al., 2014), we also examine how the structural aspects of SNSs networks are associated with loneliness. Second, most of the previous research on SNSs use and loneliness has been based on self-report data (Seabrook et al., 2016; Song et al., 2014). However, obtaining structural network data based on participants self-report is very time consuming (Hogan et al., 2007) and self-report data on both social networks (Bernard et al., 1984) and patterns of technology use (Boase & Ling, 2013; Ellis, 2019; Ellis et al., 2018) correlate poorly with data based on actual observations or actual usage. In this study, we extracted information on the size and structure of participants' Facebook Friend networks directly from the participants Facebook accounts, thus ensuring all the network properties were accurate.

In this study, we specifically focus on students, as this age group are the most frequent users of Facebook (Chenn, 2020) with 79% of those aged 18 to 29 years-old using Facebook. Further, previous research has shown students use Facebook to help in the transition to University (Gramlich, 2019) and those under 30 years have higher levels of loneliness than any other age group, other than over 65s (Lasgaard et al., 2016; Luhmann & Hawkey, 2016; Victor & Yang, 2012). Thus, examining how students' Facebook networks are associated with loneliness can provide insights into how these frequent users of SNS may use social media as they are developing and maintaining their friendships at University (Ellison et al., 2011; Gray et al., 2013; Lou et al., 2012; Roberts & Dunbar, 2015; Wohn & LaRose, 2014; Yang & Lee, 2020).

In addition to Facebook use, other individual characteristics may affect loneliness and we therefore controlled for these factors in our analyses. One important factor may be relationship status, with people in romantic relationships reporting lower levels of loneliness than people not in romantic relationships (Bucher et al., 2019).

Further, international students may face additional challenges when at University compared to students attending University in their own country, including lack of access to social support and higher levels of loneliness (Rajapaksa & Dundes, 2002; Sawir et al., 2008; Wu et al., 2015). Finally, there is some evidence from a large international survey that levels of loneliness are higher in men than in women (Barreto et al., 2021). However, a meta-analysis found that this effect may be small and only significant for children, adolescents and young adults under 40 years-old (Maes et al., 2019) and other studies suggest higher levels of loneliness in females (Nicolaisen & Thorsen, 2014). We thus controlled for relationship status, nationality and gender of the students in our analyses.

The key aim of this study was therefore to examine how the size and structure of students' Facebook networks was related to loneliness. Specifically, based on the existing literature on the size of SNSs networks and loneliness, and the associations between the structure of offline networks and loneliness, we test four hypotheses:

H1: Larger Facebook network sizes will be associated with lower feelings of loneliness.

H2: Higher Facebook network density will be associated with lower feelings of loneliness.

H3: A higher number of network clusters in Facebook networks will be associated with lower feelings of loneliness.

H4: Shorter average path lengths in Facebook networks will be associated with lower feelings of loneliness.

In measuring loneliness, a key unresolved debate is between unidimensional and multidimensional conceptualizations (Cramer & Barry, 1999). In a unidimensional conceptualization of loneliness, loneliness is characterized by a common core of negative affective experiences that would be experienced by people with a perceived lack of satisfying social relationships, whether this is, for example a lonely first year student or a lonely widow (Russell, 1996; Russell et al., 1980; Russell et al., 1984). The most commonly used scale to measure this type of loneliness is the 20-item UCLA Loneliness Scale (Russell, 1996) along with the various shortened versions of this scale (Hays & DiMatteo, 1987; Hughes et al., 2004). In contrast, other researchers argue that loneliness is multidimensional, with at least two distinct components – the emotional loneliness associated with the lack of a close, emotional attachment to another person (e.g., to a romantic partner or best friend), and the social loneliness associated with the lack of a broader network of friends (Cramer & Barry, 1999; de Jong-Gierveld & Kamphuls, 1985; de Jong-Gierveld & Van Tilburg, 2006; Ditommaso & Spinner, 1993; Weiss, 1973, 1987). This is reflected in the scales used to measure multidimensional loneliness, with separate sub-scales for emotional and social loneliness (de Jong-Gierveld & Van Tilburg, 2006), and for family loneliness in some scales (Cramer et al., 2000; Ditommaso & Spinner, 1993).

A comparison of loneliness scales demonstrated the UCLA loneliness scale principally measures social loneliness, and is less reflective of levels of emotional and family loneliness (Cramer & Barry, 1999). In this study, we used the 20-item UCLA loneliness scale (Russell, 1996), as Facebook networks may be expected to relate to maintenance of a broader social network of friends and be more closely related to social loneliness, rather than close, intimate attachments as measured by family or emotional loneliness subscales (Ditommaso & Spinner, 1993). Further, most previous research relating use of Facebook to loneliness has used the UCLA loneliness scale (Baker & Oswald, 2010; Burke et al., 2010; Burke & Kraut, 2016; Greitemeyer et al., 2014; Hunt et al., 2018; Kim et al., 2009; Lou et al., 2012; Satici, 2019; G. G. Scott et al., 2018; Skues et al., 2012; Sulaiman et al., 2018; Wohn & LaRose, 2014), and therefore using this scale in this study allowed comparison of the results across these studies, examining whether the structure as well as the size of the Facebook network is associated with loneliness.

Method

Participants

Initially, 110 participants were recruited, three of whom were excluded. This would allow us to detect a weak to moderate effect size ($r = .263$; assumed power = .8, based on two-tailed correlation test, Champely et al., 2018). Two of these excluded participants did not follow the instructions correctly and the third was classified as an extreme outlier regarding the number of Facebook Friends ($N = 1,689$, $> 4 SD$ above the mean). Therefore, the final sample consisted of 107 participants, including 36 men and 71 women ($M_{age} = 20.64$, $SD = 2.71$, range 18 to 32

years). All participants were students. The majority of participants were Dutch ($N = 95$; 88.8%) with the twelve remaining international participants (11.2%) coming from ten different countries. In terms of relationship status, 41.1% ($N = 44$) of the participants indicated they were in a committed relationship (*married or in a relationship*). Membership of Facebook was required to participate in the study. Respondents indicated their Facebook usage with items from Ross et al. (2009) Facebook questionnaire: "On average, approximately how much time per day do you spend on Facebook?" (1 = *ten minutes or less* to 6 = *three or plus hours*; $M = 2.98$, $SD = 1.16$) and "Facebook is a part of my everyday activity" (1 = *strongly disagree* to 5 = *strongly agree*; $M = 3.65$, $SD = 1.07$). The majority of our participants agreed with the statement that Facebook is part of their everyday activities (Median = 4; 60% agreed, and 14% strongly agreed). Only 10% of our sample answered that they spent less than ten minutes or less, and only 8% disagreed strongly with the statement that Facebook is part of their everyday activity. On the Open Science Foundation (OSF) page (<https://osf.io/9ep6z/>), we present Supplementary Information (SI) where these non-regular users, i.e., those who disagreed strongly that Facebook is part of their everyday activity, were excluded. Due to time constraints and the focus on Facebook social networks, we did not collect data on usage of other social media.

Procedure, Measures and Analyses

The participants were invited to come to the laboratory at VU Amsterdam and completed the study for the most part on computers in separate cubicles. They were recruited from the university's participant pool, as well as via advertisements on University message boards. Before starting, participants were provided with information that they would take part in a study named 'Facebook and Personality', with the aim to investigate their Facebook data and personal characteristics. The study took place in February 2015 and took on average 45 minutes. Each participant could choose between a compensation of 5€ or 45 study-credits.¹

First, participants were asked to log on to their Facebook profile. Participants' social network data was extracted from Facebook using the Getnet app a modified version of the Netvizz app (Adamic, 2015; Rieder, 2015). This app extracted data on the participants' Facebook friendship networks and importantly provided us with the data on who was connected to whom in their network (i.e., whether the participants Facebook Friends were Friends with each other). The application is described in full in Rieder (2013). The Getnet app was only used to extract network data, as it does not have any capability for network data analysis. We therefore transferred the Facebook network data to the open-source network analysis software Gephi (Bastian et al., 2009) for calculation of the social network measures. For each participant, four social network metrics were calculated and used in the subsequent analyses to examine how these network metrics were associated with the participants self-reported loneliness levels. We therefore used standard hierarchical regressions to test our hypotheses, with the four network metrics as the predictor variables in these regression analyses, rather than carrying out an in-depth social network analysis on each of the Facebook networks.

The number of Facebook Friends represents Facebook users' *network size*. The *network density* is computed by the number of links in a network divided by the number of all possible links (Golbeck, 2013; J. Scott & Carrington, 2011). The *number of clusters* within a network represents the number of sub-groups in the network which consist at least of 3 individuals and was calculated via the Louvain Method (Blondel et al., 2008). The Louvain method is a widely used algorithm to detect clustering in larger networks (Brooks et al., 2014), and works as follows: first, small clusters are discovered by optimizing modularity, i.e., the fraction of edges that fall within given groups minus the expected fraction if edges were distributed at random, locally on all nodes, then each small community is grouped into one node and the first step is repeated. The implementation is described in Blondel et al. (2008). The *average path length* is the average number of steps between all pairs of individuals in a network (Golbeck, 2013). To assess loneliness, we used Russell's 20-item UCLA loneliness Scale (Russell, 1996) with a 4-point Likert scale (1 = never to 4 = always) and this showed excellent internal consistency (Cronbach's $\alpha = .93$). The final loneliness variable is calculated as the average of all 20 items, with higher scores indicating more loneliness. Finally, participants reported information about their age, gender, nationality and relationship status. The ethics committee where the study was carried out approved this procedure. We did not store any identifiable personal data extracted from these Facebook network contacts, and these data were solely used for calculating the four network metrics for each participant (i.e., network size, network density, number of clusters, path length).

The analyses were conducted in R (R Core Team, 2018) using hierarchical regression analyses to explore the associations between loneliness and the network measures, with loneliness the dependent variable in all the regressions. In the first step, we examine the bivariate relationship between the network metric of interest and loneliness. Next, we considered gender, age, nationality, and relationship status as control variables, as these variables relate to loneliness (Barreto et al., 2021; Bucher et al., 2019; Rajapaksa & Dundes, 2002; Sawir et al., 2008; Wu et al., 2015). In the final step, we included nationality as an additional control variable. The data and analyses, including additional analyses such as bootstrapping Bias-Corrected Accelerated confidence intervals (BCa) (Canty, 2002; Davison & Hinkley, 1997; Efron, 1987) and robustness checks are available in the SI at <https://osf.io/9ep6z/>.

Results

Table 1 shows the descriptive statistics and bivariate Pearson correlations for all variables. There was a significant negative correlation between Facebook network size and loneliness – those with more Facebook Friends felt less lonely. However, the other three network measures (density, clusters and path length) were not significantly related to loneliness. Of the control variables, only gender was significantly related to loneliness, with women reporting lower levels of loneliness than men did.

Table 1. Means, Standard Deviations, and Pearson's Correlations of Model Variables (N = 107).

Variable	M	SD	1	2	3	4	5	6	7	8
1. Loneliness	1.56	0.48								
2. N Facebook Friends	394.08	225.84	-.24*							
			[-.42, -.06]							
3. Density	0.10	0.04	-.00	-.26**						
			[-.19, .19]	[-.43, -.08]						
4. N clusters	16.38	9.25	.04	.48**	-.59**					
			[-.15, .23]	[.32, .61]	[-.70, -.45]					
5. Avg Path length	2.66	0.43	.05	-.04	-.64**	.38**				
			[-.14, .24]	[-.23, .15]	[-.74, -.52]	[.21, .54]				
6. Gender (1 = female)	0.66	0.47	-.27**	.04	.14	-.22*	-.07			
			[-.43, -.08]	[-.15, .23]	[-.05, .32]	[-.39, -.03]	[-.25, .12]			
7. Age	20.64	2.71	.18†	-.28**	-.35**	.19*	.36**	-.32**		
			[-.01, .36]	[-.45, -.10]	[-.51, -.18]	[.00, .37]	[.18, .52]	[-.48, -.14]		
8. Nationality (1 = other)	0.11	0.32	-.00	.13	-.18	.11	.20*	-.12	.37**	
			[-.19, .19]	[-.07, .31]	[-.36, .01]	[-.08, .30]	[.01, .38]	[-.31, .07]	[.19, .52]	
9. Relationship (1 = in a relationship)	0.41	0.49	-.16†	.09	-.01	-.08	-.01	-.05	.01	-.12
			[-.34, .03]	[-.10, .28]	[-.20, .18]	[-.27, .11]	[-.20, .18]	[-.24, .14]	[-.18, .20]	[-.30, .08]

Note. M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation.

† $p < .1$, * $p < .05$, ** $p < .01$.

The first regression model examined whether network size was significantly associated with loneliness (Hypothesis 1). There was a significant negative association between network size and loneliness (Model 1). An increase of the network size of one standard deviation (about 225 friends) was predicted to decrease the amount of loneliness by approximately 0.25 standard deviations (see Figure 1). Model 2 included all variables which showed some association with loneliness and control variables, based on Table 1. Women reported significantly lower levels of loneliness than men did, those in a relationship tended to report less loneliness than those not in a relationship, albeit not significantly so ($p = .09$). Age was not significantly related to loneliness ($p = .645$). Model 3 included all the potential control variables, the association between network size and loneliness remained sizable ($\beta = -.24$ to $\beta = -.19$) but was no longer statistically significant ($p = .056$). Yet, inclusion of the additional control variables did not improve the model ($\Delta R^2 < .003$, $p = .61$), we therefore believe Model 2 is best supported. Moreover, when we bootstrap the coefficient for network size from Model 3 (95% CI: $\beta = -.41$ to $-.04$, based on 10,000 Bias-Corrected accelerated bootstraps), this lends further support to the negative relationship between network size and loneliness.

Figure 1. Relationship Between Number of Facebook Friends (i.e., Network Size) and Loneliness With Linear Regression Line and 95% Confidence Interval.

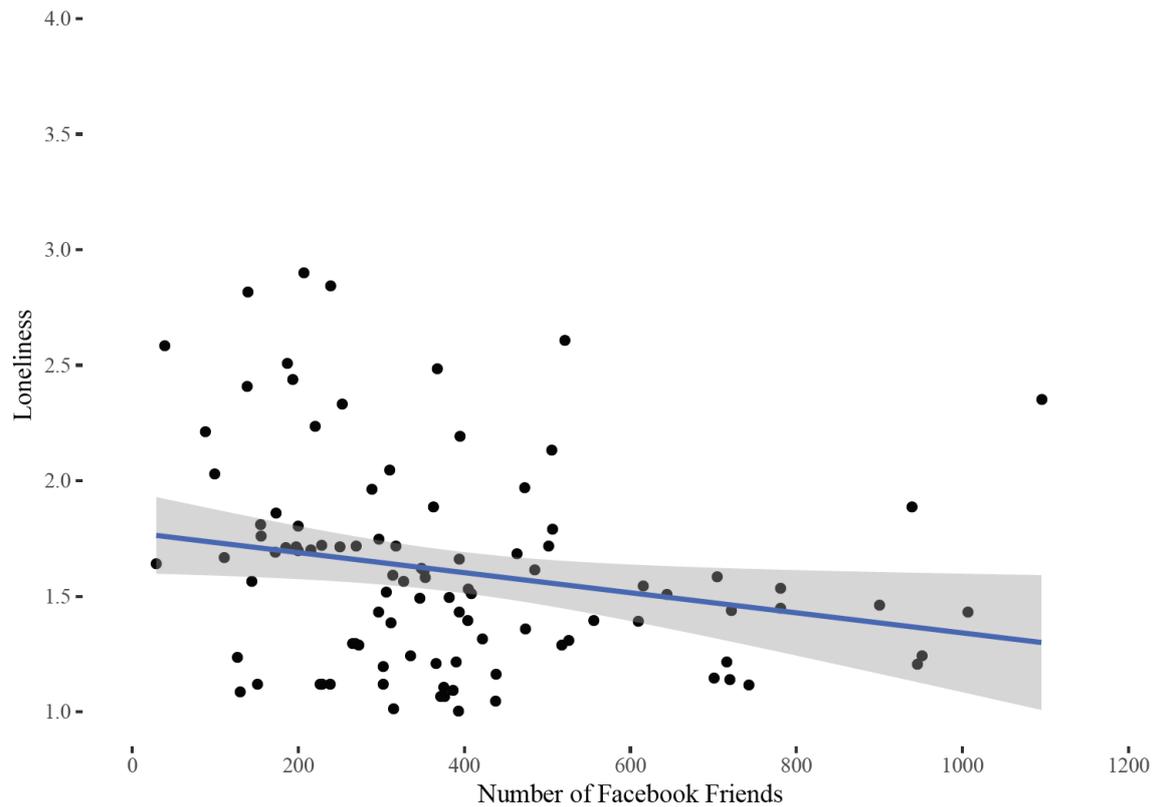


Table 2. Results of Hierarchical Regression Analysis (β , SE in Brackets and Concomitant Model Statistics) Predicting Loneliness From Facebook Network Size (Hypothesis 1, $N = 107$).

	Loneliness		
	(1)	(2)	(3)
N Facebook Friends	-0.245* (0.094)	-0.206* (0.095)	-0.192 [†] (0.099)
Gender (Male → Female)		-0.250** (0.096)	-0.250* (0.096)
Relationship status (Not in a Relationship → Relationship)		-0.15 (0.091)	-0.164 [†] (0.093)
Age		0.046 (0.100)	0.069 (0.110)
Nationality (Dutch → Other)			-0.052 (0.103)
R^2	.060	.151	.153
Adjusted R^2	.051	.118	.112
Residual Std. Error	0.970 ($df = 106$)	0.935 ($df = 103$)	0.938 ($df = 102$)
F Statistic	6.740* ($df = 1, 106$)	4.585** ($df = 4, 103$)	3.693** ($df = 5, 102$)

Note. [†] $p < .1$, * $p < .05$, ** $p < .01$.

Given that the number of Facebook Friends is skewed (visual check and Kolmogorov-Smirnov test, $p < .00001$), we applied a log-transform (\log_{10}) and ran the same hierarchical regression models. These analyses further corroborated the existence of a significant negative association between network size and loneliness, including when gender, age, relationship status and nationality are controlled for (Table 3). In the SI, we also present models with curvilinear effects for the log-transformed Facebook network size on loneliness. None of the parameter estimates supported a curvilinear effect (all $p > .54$). There were no statistically significant associations between loneliness and the other three network measures: Density (Hypothesis 2), number of clusters (Hypothesis 3) or average path length (Hypothesis 4, Table 4). Adjusting for the proposed control variables did not alter this conclusion. As the (log-transformed) number of Facebook Friends mathematically relates to density, number of clusters and average path length, we did not include network size it as a control variable in the main analyses.

However, inclusion of log-transformed Facebook network size as a control variable, does not alter our key conclusions – these models are reported in the SI.

Table 3. Results of Hierarchical Regression Analysis (β , SE in Brackets and Concomitant Model Statistics) Predicted Loneliness From Log-Transformed Number of Facebook Friends ($N = 107$).

	Loneliness		
	(1)	(2)	(3)
Log (N Facebook Friends)	-0.323** (0.092)	-0.284** (0.098)	-0.273** (0.101)
Gender (Male \rightarrow Female)		-0.240* (0.095)	-0.241* (0.095)
Age		-0.007 (0.103)	0.016 (0.112)
Relationship status (Not in a Relationship \rightarrow Relationship)		-0.154 [†] (0.090)	-0.161 [†] (0.091)
Nationality (Dutch \rightarrow Other)			-0.052 (0.100)
R^2	.104	.179	.182
Adjusted R^2	.096	.147	.141
Residual Std. Error	0.951 ($df = 105$)	0.923 ($df = 102$)	0.927 ($df = 101$)
F Statistic	12.219** ($df = 1, 105$)	5.578** ($df = 4, 102$)	4.485** ($df = 5, 101$)

Note. [†] $p < .1$, * $p < .05$, ** $p < .01$.

Table 4. Results of Hierarchical Regression Analysis (β , SE in Brackets and Concomitant Model Statistics) Predicting Loneliness From Density (Hypothesis 2), Number of Clusters (Hypothesis 3) and Average Path Length (Hypothesis 4, $N = 107$).

	Loneliness					
	(1)	(2)	(3)	(4)	(5)	(6)
Density	-0.003 (0.097)			0.071 (0.099)		
Number of clusters		0.037 (0.097)			-0.050 (0.096)	
Average path length			0.054 (0.097)			0.005 (0.100)
Gender (Male \rightarrow Female)				-0.244* (0.098)	-0.251* (0.099)	-0.242* (0.098)
Relationship status (Not in a Relationship \rightarrow Relationship)				-0.188* (0.093)	-0.193* (0.094)	-0.189* (0.094)
Age				0.169 (0.109)	0.152 (0.105)	0.144 (0.110)
Nationality (Dutch \rightarrow Other)				-0.102 (0.100)	-0.104 (0.100)	-0.107 (0.101)
R^2	.000	.001	.003	.127	.125	.122
Adjusted R^2	-.009	-.008	-.006	.084	.082	.079
Residual Std. Error	1.000 ($df = 106$)	0.999 ($df = 106$)	0.999 ($df = 106$)	0.953 ($df = 102$)	0.954 ($df = 102$)	0.955 ($df = 102$)
F Statistic	0.001 ($df = 1, 106$)	0.146 ($df = 1, 106$)	0.310 ($df = 1, 106$)	2.961* ($df = 5, 102$)	2.904* ($df = 5, 102$)	2.843* ($df = 5, 102$)

Note. [†] $p < .1$, * $p < .05$, ** $p < .01$.

Discussion

This study examined how self-reported loneliness was related to Facebook network size and structure in a sample of European students. We collected the network measures directly from the participants' Facebook networks, ensuring their accuracy and avoiding the problems associated with self-reported measures (Bernard et al., 1984; Ellis et al., 2018). Facebook users with a larger number of Facebook Friends reported lower feelings of loneliness, supporting Hypothesis 1. This finding was consistent across a series of models and control variables. There was one model where it achieved $p = .056$ rather than $p < .05$ (Table 2: Model 3), but the direction and magnitude in this model was similar to the other models (Table 2: Models 1 and 2). In contrast to the finding on size, the other

structural properties of Facebook networks (network density, number of clusters and average path length) were not significantly associated with loneliness and thus Hypotheses 2, 3 and 4 were not supported.

The finding that the number of Facebook Friends is related to lower feelings of loneliness supports the majority of previous findings in this area (Burke et al., 2010; Greitemeyer et al., 2014; Nowland et al., 2018; Phu & Gow, 2019; Wohn & LaRose, 2014), although there have been studies showing the opposite effect (Skues et al., 2012). There was no evidence of a curvilinear effect of the number of Facebook Friends on loneliness as found in previous research in relation to both number of Friends (Wohn & LaRose, 2014) and Facebook use (Wang et al., 2018). Feelings of loneliness are associated with perceived social isolation (Hawkley & Cacioppo, 2010) and having a large number of Friends on Facebook may give a greater sense of social connection to others, as users can easily share content and exchange messages with these Friends to build and maintain stronger relationships (Berezan et al., 2020; Burke et al., 2011; Burke & Kraut, 2016; Nowland et al., 2018; Yang & Lee, 2020).

Social media sites such as Facebook may be particularly useful for students in building and maintaining social relationships whilst at University (Ellison et al., 2011; Gray et al., 2013; Yang & Lee, 2020). During the transition from school to University, the social networks of students change, with friendships to old school friends becoming less emotionally intense and new friendships being formed (McIntyre et al., 2018; Oswald & Clark, 2003; Roberts & Dunbar, 2011; Saramäki et al., 2014). Partly due to this change in their social networks, loneliness is a key issue for undergraduate students, particularly in their first year at college (McIntyre et al., 2018; Nicpon et al., 2006; Wohn & LaRose, 2014). SNSs can act as 'social lubricant' to help students build friendships at University, allowing students to find out more about students they meet offline and broadcast requests for support and information (Ellison et al., 2007; Ellison et al., 2011; Gray et al., 2013; Yang & Lee, 2020). Thus, in our study, a larger network of Facebook Friends may provide students with the greater levels of easily accessible perceived social support whilst at University and thus lower feelings of loneliness, particularly the social loneliness of being part of a broad social network of friends that appears to be captured by the UCLA loneliness scale (Cramer & Barry, 1999).

However, other research in this area has found more mixed results with habitual use of Facebook associated with poorer adjustment to college, and no significant associations between Facebook use and loneliness (Wohn & LaRose, 2014). Further, having a larger Facebook network may also be at least partially reflective of a larger offline social network (Burke et al., 2011; Nowland et al., 2018; Sutcliffe et al., 2018). It may be the size of the offline network, rather than the number of Facebook Friends that is the more important factor in loneliness (Binder et al., 2012; Cacioppo et al., 2009; Hawkley et al., 2008). Further research is needed to distinguish between these two possibilities and explore the relationships between the size and quality of offline networks, Facebook networks and loneliness (Nowland et al., 2018; Sutcliffe et al., 2018). Because of the specific social circumstances of students (Gray et al., 2013; McIntyre et al., 2018; Yang & Lee, 2020), the association between SNSs networks and loneliness may be different in different groups of people, with for example SNSs found to be more beneficial in reducing loneliness in older adults as compared to late adolescents (for a review, see Nowland et al., 2018).

In contrast, the structural properties of the Facebook networks (network density, number of clusters and average path length) were not significantly associated with loneliness. This finding could be considered surprising as these network properties have been associated with loneliness (or related concepts) in offline networks (Bell, 1991; Stokes, 1985) and to social capital in Facebook networks (Brooks et al., 2014). One reason for this divergence in findings may be because patterns of information flow and social support operate differently in offline networks as compared to Facebook, where the user is more easily able to broadcast requests and access information and support from their whole network through status updates, regardless of the network structure (Brooks et al., 2014; Lampe et al., 2011; Morris et al., 2010). In contrast, in offline networks, the structure of the network contains the flow of information much more and requests for support and advice may take more time to reach less closely connected friends (Borgatti & Cross, 2003; Haythornthwaite, 1996). Alternatively, a more important influence on loneliness than network structure may be whether Facebook users actively exchange communication with people in their network, rather than using Facebook more passively (Brooks et al., 2014; Burke et al., 2011; Burke & Kraut, 2016; Lin et al., 2020; Yang & Lee, 2020). Future research comparing the network structure, information flow and support provided in offline and Facebook networks (Brooks et al., 2014; Morris et al., 2010) will provide further insights into the association between loneliness, and offline and online network structures.

An additional factor that may influence the association between loneliness and Facebook networks is gender. Males reported higher levels of loneliness than females in this study, supporting previous findings of a small but significant gender difference in loneliness in previous research in this age group (Barreto et al., 2021; Maes et al., 2019), although other research has found higher levels of loneliness in women (Nicolaisen & Thorsen, 2014). Future work could examine how gender differences in loneliness relate to activity on social networking sites such as Facebook. There is evidence of gender differences in the motivations for the use of social networking sites, with women motivated by maintaining ties with close friends and access to social information about both close and distant friends, whilst men are more motivated by access to general, non-social information (Krasnova et al., 2017; Special & Li-Barber, 2012). It could therefore be predicted that the association between a larger Facebook network and lower levels of loneliness may be more pronounced in women, as having more Facebook friends allows them to maintain close ties and have access to social information, thus reducing feelings of social isolation.

There were several limitations to this study which could be addressed in future research. First, this study used the unidimensional UCLA loneliness scale (Russell, 1996) and other researchers have argued that multidimensional scales better capture the different types of loneliness, both overall, (e.g., Cramer et al., 2000; Cramer & Barry, 1999; Ditommaso & Spinner, 1993; Gierveld & Van Tilburg, 2006; Weiss, 1987) and in relation to SNS use. For example, Wang et al. (2018) found a curvilinear relationship between active public Facebook use and both social and emotional loneliness, as well as a curvilinear relationship between emotional loneliness and active Facebook use in a large sample of adolescents. Future studies could examine how both emotional and social loneliness are associated with both Facebook network characteristics and different types of Facebook use. Second, this study measured trait loneliness (how lonely the participants felt in general), rather than state loneliness (momentary feelings of loneliness in daily life). Research using either the Experience Sample Method (e.g., van Roekel et al., 2018) or an experimental design to manipulate Facebook use (e.g., Deters & Mehl, 2013; Gonzales & Hancock, 2011; Tromholt, 2016) would be needed to examine whether Facebook use directly affects *state* loneliness.

A third limitation is that this study focused only on Facebook networks, whilst in the last decade a wide range of SNSs and messaging services have become more popular, particularly among younger users, including Twitter, Instagram and WhatsApp (Ofcom, 2018; Pittman & Reich, 2016; Yang & Lee, 2020). These SNSs have different properties which may influence how they are related to loneliness, with Instagram used to follow people not known offline as well as friends, and WhatsApp used to create more private groups (Pittman & Reich, 2016). Future research could examine how the network properties of these different types of SNSs are associated with loneliness (Mackson et al., 2019; Yang, 2016) and adjustment to University (Yang & Lee, 2020). More broadly, our study is limited by the sample it used (Henrich et al., 2010; Pollet & Saxton, 2019; Simons et al., 2017), and the degree to which our findings would generalize beyond student samples in a Western context is unclear. In this context, it is also important to acknowledge the imbalance in terms of gender of our sample. While controlling for gender did not meaningfully affect the negative relationship between Facebook network size and loneliness, future studies might benefit from a better balance in terms of gender.

Finally, as this was a cross-sectional study, we could not examine causality. Longitudinal studies are needed to examine whether less lonely people have more Facebook friends, or whether having more Facebook friends make people feel less lonely (Song et al., 2014). A recent review suggested there may be a bidirectional relationship between social internet use and loneliness, with loneliness both a consequence and determinant of social internet use (Nowland et al., 2018).

The findings of this study, together with other studies examining the associations between social media use and well-being (Burke & Kraut, 2016; Ellison et al., 2007; Ellison et al., 2011; Ellison et al., 2014; Nowland et al., 2018; Yang & Lee, 2020) may have practical implications for universities and colleges guiding students through the transition from school to higher education. Active use of social networking sites, together with a larger number of Facebook friends, appear to be associated with lower levels of loneliness. A key part of the transition to higher education is building up and maintaining a new set of friends (Azmitia et al., 2013; Oswald & Clark, 2003; Roberts & Dunbar, 2015; Veldman et al., 2019; Yang & Lee, 2020), and a successful social transition is associated with better academic performance as well as lower levels of loneliness (Gray et al., 2013; McIntyre et al., 2018). Higher education institutes can facilitate this process by setting up course or subject specific social networking groups, or encouraging students to set up their own groups, where students can build social connections with each other, supporting each other both academically and socially (for case studies of this approach, see Jackson, 2013;

Woodley & Meredith, 2012). Student use of Facebook sites for this purpose is associated with better adjustment to college (Gray et al., 2013; Yang & Brown, 2015). However, given the rapid changes in usage of different social media sites (Ofcom, 2018; Yang & Lee, 2020), in the future it will be important for Universities to use the social media platforms most applicable to their student body if using SNS as a tool for facilitating social connections between students, which may include platforms such as WhatsApp, Instagram or Twitter, rather than Facebook (Yang & Lee, 2020).

To conclude, Facebook users with larger networks reported lower levels of loneliness, but the structure of the Facebook network was not significantly associated with loneliness. This study adds to a body of research that suggests that the relationship between psychological well-being and social media use is not just related to the amount of time users spend on social media, but also to other factors such as network size, active or passive use and individual characteristics of the users (Arampatzi et al., 2018; Burke & Kraut, 2016; Nowland et al., 2018; Song et al., 2014; Yang & Lee, 2020).

Footnotes

1. The data used in this study was collected as part of a larger study which contained additional questionnaires including questions on participants' sympathy group on Facebook and in real-life (Buys & Larson, 1979), items of Ross et al.'s (2009) Facebook questionnaire (Ross et al., 2009), and the 60-item HEXACO Personality Inventory (Ashton & Lee, 2009; Molho et al., 2016).

Supplementary Information

Additional information relating to this study can be found at the OSF page: <https://osf.io/9ep6z/>

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