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Social media use and well-being: A prospective experience-sampling study

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ABSTRACT

Facebook and Instagram are currently the most popular Social Network Sites (SNS) for young adults. A large amount of research examined the relationship between these SNS and well-being, and possible intermediate constructs such as social comparison, self-esteem, and repetitive negative thinking (RNT). However, most of these studies have cross-sectional designs and use self-report indicators of SNS use. Therefore, their conclusions should be interpreted cautiously. Consequently, the goal of the current experience sampling study was to examine the temporal dynamics between objective indicators of SNS use, and self-reports of social comparison, RNT, and daily fluctuations in negative affect. More specifically, we assessed 98 participants 6 times per day during 14 days to examine reciprocal relationships between SNS use, negative affect, emotion regulation, and key psychological constructs. Results indicate that (1) both Facebook and Instagram use predicted reduced well-being, and (2) self-esteem and RNT appear to be important intermediate constructs in these relationships. Future longitudinal and experimental studies are needed to further support and extend the current research findings.

1. Introduction

Social network sites (SNS) are described as “web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system” (boyd & Ellison, 2007, p. 211). The rapid rise of SNS such as Facebook and Instagram has attracted billions of users, who use these platforms on a daily basis (Pew Research Center, 2019; Vandendriessche & De Marez, 2020). Recent estimates indicate that these mediums are most frequently used by young adults, with 79% of 18–29 year olds having a Facebook and 67% of 18 year olds having Instagram accounts, respectively.

Given the immense popularity of Facebook and Instagram among young adults, researchers started to investigate the relationship between SNS and mental health (e.g., Berry, 2004). However, the results of these studies are inconclusive. Whereas several studies found a negative relationship between Facebook use (Blachnio et al., 2016; Satici & Uysal, 2015; Shakya & Christakis, 2017; Verduyn et al., 2015), Instagram use (Frison & Eggermont, 2017; Fardouly et al., 2018; Sherlock & Wagstaff, 2018) and well-being, others found no association, a

negligible association (Jelenchick et al., 2013; Vannucci et al., 2019), or even a positive association (Grieve et al., 2013; Mackson et al., 2019; Park & Lee, 2014; Valenzuela et al., 2009, Yang & Lee, 2020). Meta-analytic results reported by Huang (2017) mainly support the (small) negative association between SNS use and well-being ($r = -0.07$). Importantly, the associations obtained depended on the indicator of mental health. That is, the overall relations between SNS use and negative mental health outcomes such as depression and loneliness were negative but weak. The mean relations for positive indicators such as self-esteem and life satisfaction, however, were close to zero. These results are in line with the conclusions of the meta-analytic review of Yoon (2019), who also found a small positive association ($r = 0.11$) between time spent on SNS and depressive symptomatology. Although both meta-analytic studies suggest that SNS use is linked to reduced well-being, it is important to note that the obtained effect sizes are rather small (Cohen, 1992). In addition, there was also large heterogeneity in the effect sizes observed across the included studies (e.g., Yoon, 2019). Given the high prevalence of SNS use in modern society, this finding points to the importance of research focused on increasing our understanding on how SNS use impacts well-being. In particular, it remains unclear which psychological constructs or individual differences may be

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involved as possible mediators or moderators in this relationship.

An investigation of the underlying processes and mechanisms is important to understand the inconsistent results obtained for associations between SNS use and mental health. Recently, multiple candidate intervening variables have been forwarded. For example, Verduyn et al. (2017) suggested *social comparison* as a possible mediator in the negative relationship between SNS use and well-being. Festinger (1954) proposed that human beings have a tendency to compare themselves with others in order to assess their opinions and abilities. More specifically, he made a distinction between upward and downward social comparison. Upward comparison takes place when comparing oneself with someone who is considered to be superior, whereas downward comparison occurs when comparing oneself with someone inferior. The rise of SNS has made information about others more accessible than ever, thereby increasing the likelihood that people engage in social comparison and in upward comparison in particular. Indeed, SNS such as Facebook and Instagram provide ample opportunity for selective and favorable self-presentation. As a consequence of the chronic exposure to a high amount of idealized information, users may evaluate themselves more negatively and feel less satisfied with their lives (Appel et al., 2016; Chou & Edge, 2012). Research has indeed shown that being exposed to attractive pictures leads to negative affect and decreased self-esteem (Vogel et al., 2014).

Because the engagement in social comparison associated with SNS use may have repercussions for self-worth, it is important to consider the role of self-esteem in associations between SNS use and mental health. *Self-esteem* has been defined as an individual's overall evaluation of self-worth (Rosenberg et al., 1995). Abundant research has investigated the relationship between trait self-esteem and well-being, showing that high self-esteem is related to positive outcomes such as life satisfaction (e.g., Diener & Diener, 1995), whereas low self-esteem is typically linked to negative outcomes, including psychopathology (e.g., Sowislo & Orth, 2013). However, theory (Kernis, 2003) and research (Okada, 2010) suggest that self-esteem is a rather complex construct that also has dynamic aspects. Indeed, previous studies indicated that it is important to take into account not only individuals' basic level of self-esteem but also fluctuations in self-esteem (e.g., Franck & De Raedt, 2007). This may be especially important in a social media context, since SNS have the potential to affect individuals' temporary states of self-esteem, suggesting that self-esteem may be mood-reactive in this context (e.g., Clasen, 2015; Vogel et al., 2014). With regards to the fluctuations in self-esteem the construct *contingent self-esteem* (e.g., Crocker & Wolfe, 2001) seems of importance. This construct describes the degree to which one's self-esteem depends on certain self-relevant standards (Kernis et al., 2008; Paradise & Kernis, 2002; Sowislo et al., 2014). For instance, someone may only feel attractive and worthy if a profile picture receives at least 100 likes. However, if they fail to achieve this goal (e.g., by getting for example only 80 likes), this can lead to a sudden decrease in self-esteem. Therefore, this construct may be of direct relevance in a social media context, where users are constantly exposed to an enormous amount of self-relevant information (e.g., attractive pictures of others, likes, and comments). In particular, individuals whose self-esteem depends on social feedback via SNS, seem to be at risk for ill-being (e.g., Kanat-Maymon et al., 2018; Sabik et al., 2019).

Another purported mechanism that could be crucial in linking social comparison and self-esteem to mental health is *repetitive negative thinking (RNT)*. In particular, social comparison on SNS may give rise to elevated levels of RNT (e.g., prompting thoughts such as "Why are others more happy than I am?"), which is likely to impact self-esteem, and vice versa. Indeed, cross-sectional research suggests that SNS use is associated with elevated levels of RNT, where it has been suggested that RNT may mediate the relationship between the passive consumption of (strategically presented) information and social anxiety (e.g., Shaw et al., 2015). Importantly, Feinstein et al. (2013) provided longitudinal evidence for the mediating role of RNT in the relationship between negative social comparison on SNS and depressive symptomatology. As such, in

addition to social comparison and self-esteem, RNT may be an important construct to take into account when modeling the relationship between SNS use and well-being.

Overall, relatively few studies have studied the complex interrelations between SNS use, self-esteem, RNT, and mental health. In a previous set of cross-sectional studies, we used network analysis to model the unique pathways between self-reported SNS use and psychopathology (Faelens et al., 2019). These studies showed that: (1) SNS use was linked to more social comparison, (2) social comparison linked SNS use with self-esteem, and (3) self-esteem linked social comparison with rumination and reduced well-being (i.e., symptoms of depression, anxiety, and stress). These findings were recently replicated in a third large-scale cross-sectional study (Faelens et al. under review). Although informative, these initial studies had a number of limitations. First, as is the case for most studies in the SNS literature, they relied on a cross-sectional design, which does not permit to address the direction of effects in associations between studied variables. For this purpose, temporal dynamics should be taken into account, suggesting the need for prospective designs (Bos et al., 2017). Second, the majority of studies relied on self-report measures of SNS use, which are susceptible to recall bias (e.g., Thomée, 2018). Indeed, research has shown that estimates of smartphone or SNS usage may significantly differ from actual usage (e.g., Boase & Ling; Junco, 2013). More specifically, several researchers have argued that self-report questionnaires are not suitable for measuring habitual processes (e.g., Ellis et al., 2018; Stacy, 1997). Therefore, results obtained with self-reports of SNS use should be interpreted cautiously.

Addressing these limitations, the aim of the current study was to examine the temporal relations between SNS use and wellbeing, taking into account other factors such as social comparison, (contingent) self-esteem and rumination which are likely implicated in this relationship. This study contributes to the literature in a number of ways. First, provided that there are likely to be immediate effects of SNS use on social comparison and self-esteem, fluctuations and relations between these constructs need to be examined in a dynamic fashion and using a fine-grained timescale. For this purpose, we relied on experience sampling modeling (ESM), a methodology rarely used in research on SNS use to date (but see Aalbers et al., 2019; Kross et al., 2013). Second, in order to prevent problems with incorrect or socially desirable estimations of SNS use, we opted to use monitoring software. Third, findings from previous studies are typically limited to one SNS platform, whereas participants often use a combination of multiple platforms (e.g., Vandendriessche & De Marez, 2019). Since Facebook and Instagram are currently the most popular platforms for young adults in Belgium, we focused on those SNS (e.g., Vandendriessche & De Marez, 2019). Fourth, in order to capture the complexity of interrelationships between SNS use and various psychological mechanisms and well-being, we relied on a network approach. Each of these issues is discussed in greater detail below.

We used ESM (Csikszentmihalyi & Larson, 1987), a structured diary technique, to assess moment-to-moment fluctuations in participants' tendency to compare oneself on SNS, self-esteem, RNT, and negative affect. The advantage of this methodology is that it decreases recall bias associated with retrospective report and increases the reliability and ecological validity (Hektner et al., 2007). Furthermore, while prior research used self-report measures to assess participants' SNS use (e.g., Aalbers et al., 2019), we used monitoring software which was installed on participants' smartphones, tablets, laptops, and/or desktops. The first advantage of monitoring software is that it gives a more accurate estimate of the intensity of SNS use because it is not affected by recall bias. Second, the monitoring software runs in the background. Consequently, it assesses which applications or websites are being used in a discrete way.

Next, we used network methodology to quantify the dynamic interplay between our constructs of interest. That is, network analysis allows to explore the interrelationships between our constructs of interest in a

data-driven manner (Borsboom & Cramer, 2013; Bringmann & Eronen, 2018). Furthermore, this rather novel analytical approach allows visualization of complex data in an intuitive manner. As such, the application of network analysis to time series data on use of SNS, indicators of self-esteem, social comparison, RNT, and negative affect holds potential to facilitate our understanding of the relation between SNS use and psychological well-being.

Network models consist of nodes, representing the constructs included in the analysis, and edges, representing the observed links between these constructs (Borsboom & Cramer, 2013). Importantly, recent statistical and methodological developments allow the application of network analysis to model the dynamic interplay between psychological constructs (Bringmann et al., 2016; Epskamp et al., 2018). Such analyses allow computation of temporal, contemporaneous, and between-subjects networks (e.g., Aalbers et al., 2019; Hoorelbeke et al., 2019). For the purpose of the current study, the temporal and contemporaneous network models are most relevant. *Temporal networks* depict the lagged associations between the constructs of interest from one point in time (time $t-1$) to the next (time t). *Contemporaneous networks*, on the other hand, visualize the associations between the constructs within the same timeframe. For instance, Aalbers et al. (2019) recently used network analysis to model the relation between fluctuations in self-reported SNS use and depressive symptoms, where they hypothesized to find positive temporal relations between passive SNS use and depressive symptomatology. In contrast to their expectations, self-reported passive SNS use did not predict fluctuations in depressive symptomatology (temporal network). However, self-reported passive SNS use was positively associated with co-occurring depressive symptoms, among which concentration problems, fatigue, loss of interest, and loneliness (contemporaneous network). In contrast to temporal network models, contemporaneous network models do not allow to draw conclusions regarding the direction of effects, limiting the extent to which they allow to infer causation. At the same time, however, it has been argued that these contemporaneous network models may better capture fast-paced action (Epskamp et al., 2018). That is, psychological processes are likely to operate at a fast pace, which may not be fully captured by ESM periods which typically use timeframes of multiple hours. As such, plotting both temporal and contemporaneous network models may allow for a more detailed understanding of the relations between SNS use, negative affect, and intervening variables, allowing to generate specific hypotheses to be tested in future confirmatory studies.

In sum, the current prospective study aims to extend prior work by combining advanced methodological techniques (ESM, log data for SNS use, network analysis) to gain insight in the dynamic relations between SNS use, social comparison, self-esteem, RNT, and fluctuations in negative affect in daily life.

Building on previous cross-sectional findings (Faelens et al., 2019), our first aim is to model the temporal order by which use of Facebook predicts fluctuations in negative affect, taking into account the role of social comparison, self-esteem, and RNT. For this purpose, we will compute a temporal network including Facebook use, social comparison, self-esteem, RNT, and negative affect. Due to the lack of prospective studies modeling the predictive relation between the constructs of interest, formulation of clear temporal hypotheses is complicated. However, we expected that (1) Facebook use would be a significant predictor of negative affect, and that (2) social comparison, self-esteem, and RNT would be important intermediate constructs in this relationship.

Next, after controlling for temporal effects, we will model patterns of co-occurring activity between Facebook use and the constructs of interest through a contemporaneous network. Together with the findings of the temporal network, this will allow for a more detailed understanding of how Facebook use relates to indicators of well-being in daily life. Again, based on previous cross-sectional studies (Faelens et al., 2019; Faelens et al. under review), we expected that Facebook use would be related to negative affect via social comparison, self-esteem and RNT as intermediate constructs.

Finally, for exploratory purposes, given the limited amount of former research exploring the relation between the constructs of interest and Instagram use, we will also compute a temporal and contemporaneous network model reflecting the relation between Instagram use and (fluctuations in) self-esteem, RNT, and negative affect in daily life. Due to the fact that both Facebook and Instagram are strongly image-based SNS, we expected that similar associations would be observed as in the Facebook networks. More specifically, we hypothesized that Instagram would be related to negative affect via social comparison, self-esteem, and RNT. At the same time, however, given that Instagram is a different SNS, the possibility exists that the relation between Instagram use and negative affect runs via somewhat different mechanisms.

2. Method

2.1. Inclusion and exclusion criteria

This study is part of a larger project which comprised four phases: telephonic screening, baseline assessment, ESM-phase of 14 days, and a follow-up assessment. The current study reports the findings from the ESM-phase. Given that we were aiming to attract young adult SNS users, participants were recruited via Facebook, Instagram posts, and advertisements. In order to take part in the study, participants had to meet the following criteria: (1) aged between 18 and 35 years; (2) own a Facebook and Instagram account; (3) have an Android smartphone (for the purpose of monitoring Facebook and Instagram use). We focused on Facebook and Instagram since these are the two most popular SNS in Belgium. This study has been conducted in accordance with the Declaration of Helsinki and was approved by the local ethical committee of the Faculty of Psychology and Educational Sciences of Ghent University. Informed consent was obtained from all participants.

2.2. Materials

2.2.1. Software

The current study used monitoring software to collect data on participants' Facebook and Instagram usage during the ESM-phase. More specifically, the logging application mobileDNA (<https://play.google.com/store/apps/details?id=be.ugent.mobiledna&hl=nl>) was downloaded on the participants' smartphone to capture precise information on how much time participants spent on Facebook or Instagram via their smartphone. Participants were not able to see their own screen time during the study. Since the application was not supported by IOS, participants needed to have a smartphone with an Android operating system in order to be eligible for participation in the study. Via the free version of the software package ManicTime (<https://www.manictime.com>), we monitored participants' Facebook and Instagram screen time via their laptops and tablets. This monitoring software could be installed on computers/tablets with an Apple, Windows, Android, or Linux operating system. Participants were provided a manual with installation instructions following the telephonic screening, which allowed the logging of Facebook and Instagram use before the onset of the ESM-procedure.

2.2.2. ESM-items

We used ESM to assess the dynamic interplay between Facebook/Instagram use, social comparison, self-esteem, RNT, negative affect for 14 consecutive days.

Participants received text-messages six times per day between 10am and 8pm via the web-based application SurveySignal (Hofmann & Patel, 2015). Text-messages occurred at fixed intervals of 2 h (10am, 12pm, 2pm, 4pm, 6pm, 8pm). Each text message contained a unique link to an online survey, assessing the psychological constructs of interest. Participants were requested to complete the assessment within the next 30 min of receiving the signal. A reminder signal was sent if no response was given within 15 min. To enforce timely responses, the link(s) timed

out 30 min after the first signal was sent.

An initial pool of items was adapted from the study of Hoorelbeke et al. (2016). Additional items were added for the purpose of the current study. Before the start of the study, all items were piloted in a sample of 7 participants during a period of one week, after which a focus group took place. In this focus group we discussed the design of the study and the included questionnaires and ESM-items. Based on the comments and suggestions of the participants, where the focus group suggested the use of “filler items” to prevent a heavy focus on negative aspects of SNS use, we ended up with a final survey of 19 items, 9 of which are included in the analyses presented in the current manuscript (Table 1). Participants were instructed to rate each item with regards to the interval between the current and previous text-message they responded to. Possible responses ranged from 0 (“not at all”) to 100 (“very much”).

Two items measured the extent to which participants non-directionally compared themselves with others on Facebook or Instagram. These items were developed based on the Comparison Orientation Measure-Facebook (COMF; Steers et al., 2014). Similarly, we relied on the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965) and the Contingent Self-Esteem Scale (CSS; Paradise & Kernis, 1999) to develop two self-esteem items, with one item rating the extent to which they felt insecure (i.e., low level of self-esteem) and the other one measuring the extent to which their self-esteem depended on others (i.e., contingent self-esteem).

The level of RNT was assessed using one item, prompting participants to rate the extent to which they worried since the previous signal they responded to. This item was based on the Ruminative Responses Scale (RRS; Treynor et al., 2003). In addition, we assessed the extent to which participants reported being in a negative affective state (angry, tense, sad, anxious), using items adapted from Hoorelbeke et al. (2016). The indicators of negative affect were combined in a composite score for negative affect (ranging from 0 to 100, in line with the other items). A higher score on the composite measure for negative affect reflects being in a more negative affective state (ICC = 0.48).

2.3. Data-analysis

Data analysis was conducted in R (version 3.6.1; for detailed information of all packages involved, see Supplemental materials). Participants were included in the analyses if self-report data and log data on use of Facebook and Instagram was available for $\geq 50\%$ of the assessments.

Assumption check. In line with Bringmann (2016) and Aalbers et al. (2019), we relied on the Kwiatkowski-Phillips-Schmidt-Shin Unit Root

Table 1
ESM-items.

| Items | Construct |
|--|--|
| Since the previous signal, I have ... (Please indicate by entering a value from 0 (not at all) to 100 (very much)) | |
| Compared myself with others on Facebook | Non-directional social comparison on Facebook |
| Compared myself with others on Instagram | Non-directional social comparison on Instagram |
| Since the previous signal, I have ... (Please indicate by entering a value from 0 (not at all) to 100 (very much)) | |
| Felt insecure | Self-esteem |
| Since the previous signal ... (Please indicate by entering a value from 0 (not at all) to 100 (very much)) | |
| The feeling I had about myself depended heavily on what others thought of me | Contingent self-esteem |
| Since the previous signal, I have ... (Please indicate by entering a value from 0 (not at all) to 100 (very much)) | |
| Worried | Repetitive negative thinking |
| Felt angry | Negative Affect |
| Felt tense | Negative Affect |
| Felt sad | Negative Affect |
| Felt anxious | Negative Affect |

test (Kwiatkowski et al., 1992) to test for stationarity of the data. In addition, Kolmogorov-Smirnov tests were used to test whether the variables of interest followed a normal distribution. To account for multiple testing, Bonferroni correction was used.

Network analysis. To address our research questions, we conducted two separate network analyses. First, based on the cross-sectional findings of Faelens et al. (2019), we modeled the relation between intensity of Facebook use, as indicated by an objective indicator for Facebook use, and fluctuations in self-reported social comparison on Facebook, (contingent) self-esteem, RNT, and negative affective state. Second, for exploratory purposes, we re-ran these analyses with Instagram use and self-reported social comparison on Instagram.

For both SNS, we computed a temporal and contemporaneous network model using the *mlVAR* package (version 0.4.4; Epskamp et al., 2017). The networks were obtained using a two-step multilevel vector autoregressive (VAR) approach (Epskamp et al., 2018). Only the significant connections are visualized in the network model.

First, for each of the nodes in the model, performance at time t is predicted by performance at time $t-1$ of all other nodes, including an autocorrelation for the dependent variable. As a result, six multiple regression equations are estimated, where – due to the operationalization of the items – $t-1$ refers to the last signal the participant responded to. Variables are centered using within-subject centering. This first computational step allows estimation of the *temporal network models*, where edges are directed and reflect the unique prediction of one node at time $t-1$ to another node at time t . Second, residuals stemming from the first step are used in multilevel regression models, where residuals of one node at time t are predicted by all other nodes at time t . This allows estimation of the *contemporaneous network models* which reflect patterns of co-occurring activity (Epskamp et al., 2018), modeling how use of SNS relate to social comparison, self-esteem, RNT, and negative affect within each assessment period. The obtained coefficients are plotted as network models using the *qgraph* package (version 1.6.4; Epskamp et al., 2012). The network models only include edges that are significantly different from zero, where edge thickness reflects strength of connectivity. Positive associations are presented as blue lines, whereas negative associations are presented as red/dashed lines. In the temporal network models, the arrows indicate the direction of effects from time $t-1$ to time t . The contemporaneous network models, however, are undirected. For the latter models, two coefficients are obtained per pair of nodes (i.e., one stemming from the model where X is predicted by Y, taking into account the impact of the other nodes, and a second coefficient stemming from the model where Y is predicted by X). To avoid false positive edges, edges were only included in the contemporaneous network model if they appeared as significant in both regression models (AND-rule). Network models were plotted using the Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991), positioning nodes in the model based on their level of connectivity. As such, strongly connected nodes take a more central position in the network, whereas less connected nodes are positioned in the periphery of the network.

3. Results

3.1. Sample characteristics

Following the screening procedure, 107 participants entered the study, of which 2 withdrew because the study was more time-consuming than expected. In addition, 7 participants - for which available data was $< 50\%$ - were excluded from the analyses. Consequently, the final sample consisted of 98 participants (ratio male: female = 24 : 74; age: $M = 22.39$, $SD = 3.08$). Within the obtained sample, 81.68% of assessments were completed (in the presence of logs of Facebook/Instagram use), resulting in a total of 6724 unique observations within a time frame of two weeks. Sample statistics and intraclass correlations (ICC) for the variables of interest are reported in Table 2.

3.2. Assumption check

The results from the Kwiatkowski-Phillips-Schmidt-Shin Unit Root tests suggest that the assumption of stationarity was met for each of the variables included in the network (Bonferroni corrected $ps > .05$). However, the Kolmogorov-Smirnov tests suggested that normality could not be assumed for the distribution of our variables and their corresponding within-person means (all Bonferroni corrected $ps < .05$). In particular, we detected right-skew or kurtosis > 2.00 for Facebook Use, Instagram Use, Social Comparison on Facebook, and Social Comparison on Instagram and Negative Affect.¹

3.3. Temporal facebook network

We first modeled the temporal relations between Facebook use and our variables of interest. The obtained temporal network (Fig. 1) indicates that Facebook use plays a key role in the model, linking change in social comparison, self-esteem, RNT, and negative affect over time to one another. That is, the amount of time spent on Facebook at time $t-1$ was the only node uniquely predicting the state of each of the other nodes at time t . In particular, use of Facebook at time $t-1$ predicted more subsequent social comparison, increased RNT, increased negative affect, and reduced self-esteem at time t , as shown by positive relations between Facebook use, feeling insecure, and the contingent self-esteem item. Contingent self-esteem predicted feeling more insecure at time t . Moreover, each of the self-esteem items predicted more future social comparison on Facebook. Finally, as mentioned before, Facebook use predicted feelings of insecurity, RNT, and negative affect at time t , which are all strongly interrelated as shown by the bidirectional pathways between RNT, feelings of insecurity, and negative affect.

Given that each of these nodes show significant positive autocorrelations, with the exception of Facebook use itself, our results suggest that initial social media use may potentially have a longer lasting impact on psychological well-being, activating multiple self-reinforcing nodes and feedback loops. The corresponding adjacency matrix is added as supplemental material.

3.4. Contemporaneous facebook network

Second, we computed a contemporaneous network to model how use of Facebook and social comparison on Facebook uniquely related to RNT, (contingent) self-esteem, and negative affective state within the same measurement period. Although this network is strictly undirected, and as such allows no interpretations regarding direction of effects, it is likely that associations captured within such a model may reflect more

Table 2
Sample Characteristics.

| Variable | M | SD | ICC |
|--------------------------------|--------|--------|-----|
| Facebook Use (in seconds) | 686.12 | 814.63 | .18 |
| Instagram Use (in seconds) | 342.24 | 463.68 | .17 |
| Social Comparison on Facebook | 3.29 | 5.62 | .30 |
| Social Comparison on Instagram | 4.32 | 7.74 | .22 |
| Repetitive Negative Thinking | 18.06 | 15.88 | .49 |
| Feeling Insecure | 16.56 | 15.41 | .45 |
| Contingent Self-Esteem | 17.15 | 13.45 | .50 |
| Negative Affect | 12.16 | 10.41 | .48 |

Note: Ms and SDs refer to within-subject Ms/SDs.

¹ In order to evaluate effects of violation of this assumption on the robustness of our results, in line with Aalbers et al. (2019) we re-ran the network analyses using log transformation where adequate. Results stemming from these sensitivity analyses are similar to the findings presented in the current manuscript and are added as supplemental materials.

fast-paced interactions between the variables of interest. The obtained contemporaneous network (Fig. 2; for the adjacency matrix, see supplemental material) suggests that time spent on Facebook is uniquely related to social comparison on the platform, with social comparison in turn linking Facebook use to the other constructs of interest. In particular, social comparison was positively related to co-occurring RNT, feeling insecure about oneself, and the contingent self-esteem item. Contingent self-esteem and feeling insecure were positively related. RNT and feeling insecure showed positive associations with current negative affective state. In addition, self-esteem showed a positive association with RNT.

3.5. Instagram networks

Third, for exploratory purposes, we then continued modeling the temporal relationship between Instagram use, social comparison on Instagram, and our variables of interest (Fig. 3a). In line with the pattern of results stemming from the analysis of Facebook use, time spent on Instagram emerged as one of the most connected nodes in the temporal network. In addition, Instagram use at time $t-1$ predicted more social comparison, RNT, feeling insecure, and worsening of mood at time t . Contingent self-esteem predicted social comparison on Instagram and feeling insecure. Feeling insecure was bidirectionally related with both RNT and negative affect. In addition, there was also a bidirectional relation between RNT and negative affect. Compared to the temporal network of Facebook use, Instagram use did not predict future contingent self-esteem. In addition, feeling insecure about oneself did not predict future social comparison on Instagram. Instead, we observed a positive relation between RNT and future social comparison on Instagram and a negative relationship between negative affect and future social comparison. Again, each of the nodes except for the indicator of time spent on Instagram showed a significant positive autocorrelation.

Finally, using a contemporaneous network we modeled how Instagram use and social comparison on Instagram uniquely related to (contingent) self-esteem, RNT, and negative affective state within the same measurement period (Fig. 3b). We only observed a negative association between Instagram use and the contingent self-esteem item. In line with the contemporaneous network of Facebook use, social comparison on Instagram showed a positive association with feeling insecure, contingent self-esteem and RNT. Negative affective state again demonstrated positive associations with RNT and feeling insecure, which were also positively related. In addition, contingent self-esteem also showed positive associations with feeling insecure and RNT.

4. Discussion

A large body of research focused on the relationship between SNS use and well-being, and constructs that may be involved in this relationship. However, the vast majority of these studies are cross-sectional in nature, which limits making inferences about the direction of effects. To circumvent this problem, we conducted a prospective study that models the interrelations between SNS use, social comparison, self-esteem, RNT, and negative affect. Moreover, we attempted to address limitations of previous research by combining experience sampling modeling, SNS monitoring software, and network analyses. Based on initial findings reported by Faelens et al. (2019), we expected that social comparison, self-esteem, and RNT would be important constructs playing an intervening role in the relationship between Facebook use and well-being. Below we will discuss the results of the temporal and contemporaneous networks which depict the dynamic interplay between our constructs of interest.

The temporal Facebook network showed that time investment on Facebook was a significant predictor of all the psychological processes and indicators of well-being that were included in the network. Specifically, Facebook use at time $t-1$ predicted higher levels of subsequent social comparison, decreased self-esteem, increased RNT, and negative

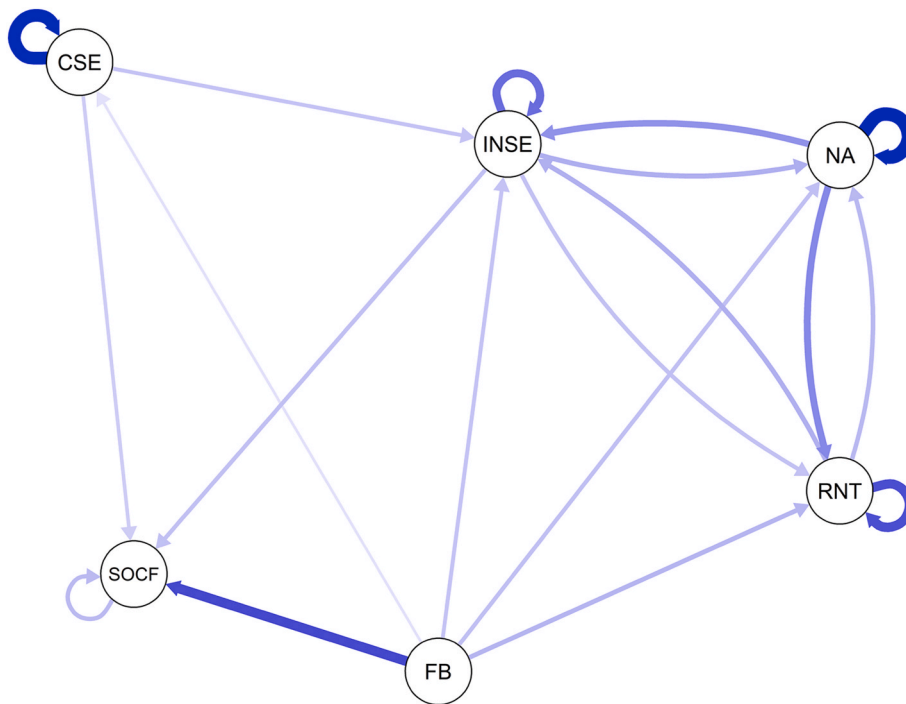


Fig. 1. Temporal network model of Facebook use. Note: Edges in the temporal network represent the unique temporal associations between each of the constructs of interest. For example, an arrow from construct Facebook to construct rumination represents a unique temporal association between Facebook at t-1 to rumination at t. Edge thickness reflects the strength of the temporal association, where strong associations are presented using thicker edges. Blue/Full edges represent positive associations, whereas red/dashed edges represent negative associations. FB = Facebook Use, SOCF = Social Comparison on Facebook, INSE = Feeling Insecure, CSE = Contingent Self-Esteem, RNT = Repetitive Negative Thinking, NA = Negative Affective State.

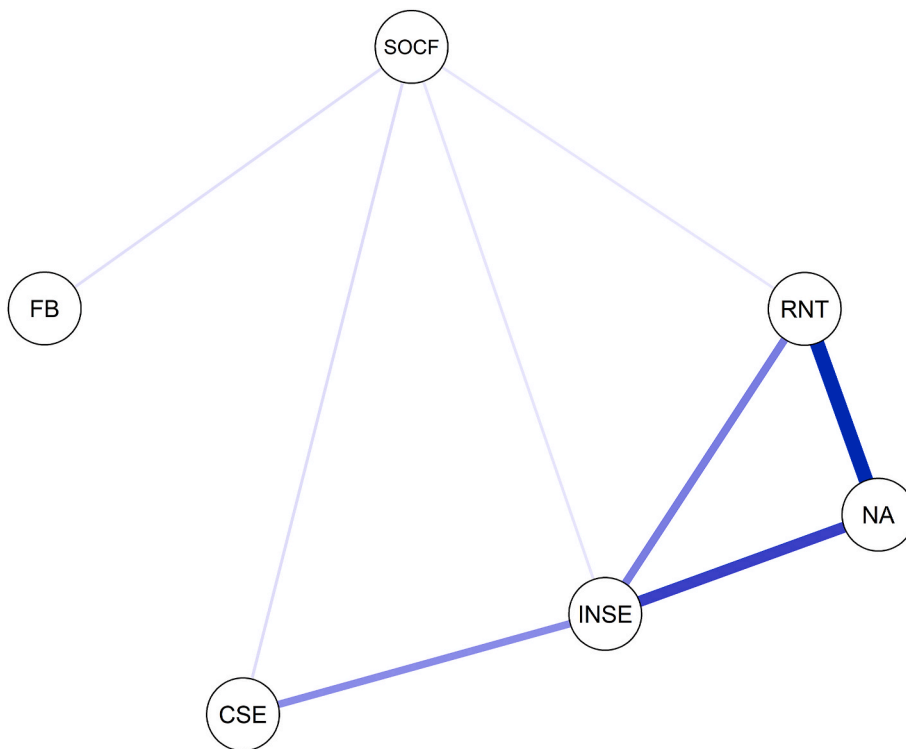


Fig. 2. Contemporaneous network model of Facebook use. Note: Edges in the contemporaneous network represent patterns of co-occurring activity. Edge thickness reflects the strength of association, where strong associations are presented using thicker edges. Positive correlations are presented as blue lines, whereas negative associations are presented as red/dashed lines. FB = Facebook Use, SOCF = Social Comparison on Facebook, INSE = Feeling Insecure, CSE = Contingent Self-Esteem, RNT = Repetitive Negative Thinking, NA = Negative Affective State.

affect at time t , which is in line with previous longitudinal and experimental research findings (Feinstein et al., 2013; Kross et al., 2013; Verduyn et al., 2017; Vogel et al., 2014). Interestingly, none of these relations appeared to be bidirectional. That is, future time investment on Facebook was not predicted by any of the included constructs. This finding is consistent with previous experience sampling studies examining the relationship between Facebook use and affective well-being. For instance, in a two week ESM-design, Kross et al. (2013) found that

participants' affective state did not predict future Facebook use. Concerning the other constructs, we are not aware of any prospective studies that explicitly examined the influence of social comparison, self-esteem, or RNT on future Facebook use.

In addition to the observed immediate effects of Facebook use on indicators of well-being, we also expected to observe indirect effects linking SNS use to well-being. In particular, based on earlier cross-sectional findings we expected that Facebook use would be related to

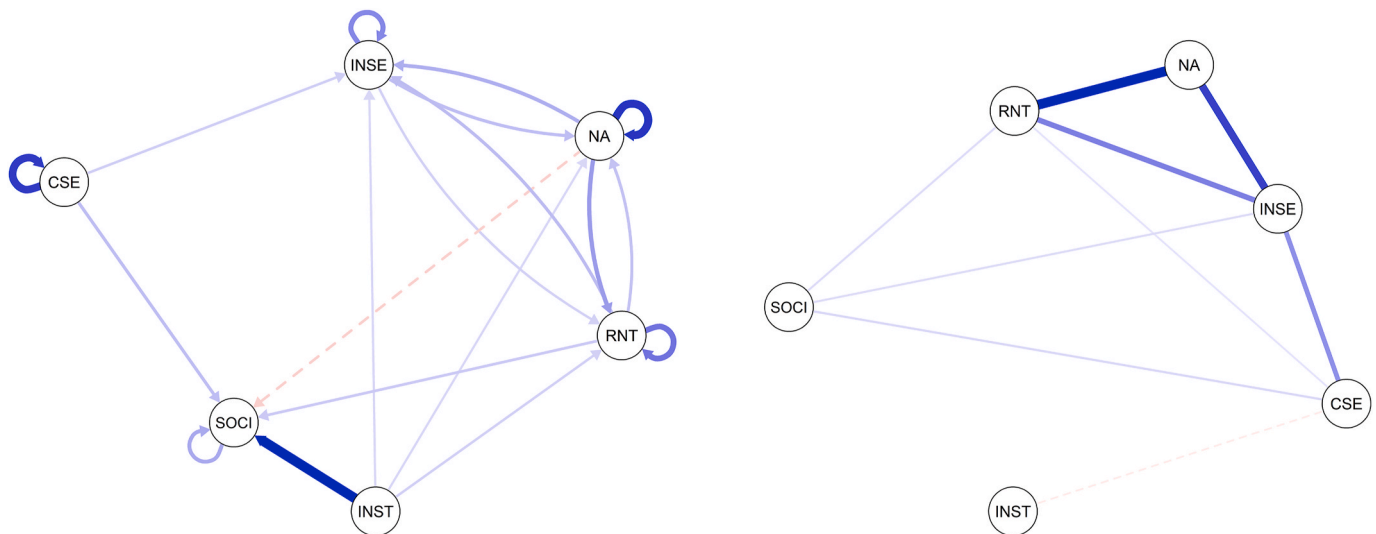


Fig. 3. Temporal and contemporaneous network models of Instagram use.

Note: (a) Left panel: Temporal Network of Instagram Use; Right panel (b) Contemporaneous Network of Instagram Use; INST = Instagram Use, SOCI = Social Comparison on Instagram, INSE = Feeling Insecure, CSE = Contingent Self-Esteem, RNT = Repetitive Negative Thinking, NA = Negative Affective State.

social comparison and self-esteem, via which it would predict RNT and negative affective state. Our research findings partially support this hypothesis. Importantly, in line with our hypothesis, our results support a more prominent role of feelings of insecurity and rumination in the dynamic relation between Facebook use and negative affect. More precisely, contingent self-esteem predicted decreases in self-esteem, which in turn predicted an increase in repetitive negative thinking and subsequent negative affect. Moreover, (1) the *bidirectional* relationships between self-esteem and RNT, self-esteem and negative affect, and RNT and negative affect, (2) the *unidirectional* effect of self-esteem on social comparison, and (3) the *positive autocorrelations* for each of these constructs, may illustrate how these effects mutually reinforce and sustain each other.

However, in contrast to our expectations we did not find any effect of self-reported social comparison on Facebook on self-esteem, RNT, or negative affect. A possible explanation for this (null) finding is that social comparison may be a psychological process that operates at a fast pace (e.g., operating within minutes), and therefore is not fully captured when modeling lagged effects using ESM methodology with lags of multiple hours. Notably, most studies examining the directional effects of social comparison on well-being are experimental studies. In these studies, participants are usually exposed to an upward comparison target, after which effects on mood and self-esteem are registered immediately (e.g., Vogel et al., 2014). Another possible explanation is that participants may not be fully aware of ongoing social comparison processes (for a meta-analytic review see: Want, 2009), which could explain the relative low levels of self-reported social comparison within our sample (Table 2). Consequently, our explicit self-report measurements may not be able to capture the effects of these (nonconscious) processes (Henderson-King et al., 2001; Verduyn et al., 2015) on self-esteem, RNT, and negative affect. Next, our social comparison item was non-directional by nature. However, since especially upward comparison on SNS is linked to negative outcomes, it is possible that our item did not fully capture its detrimental effects. Consequently, future studies should distinguish between upward and downward social comparison.

In this context, it is interesting to note that - although undirected - the expected association between Facebook use and social comparison did emerge in the *contemporaneous network*. In the contemporaneous network, Facebook intensity was uniquely linked to social comparison on Facebook, which in turn links Facebook intensity to the indicators of self-esteem and RNT, which were positively related. Subsequently, both

feelings of insecurity and RNT were positively related to negative affective state. These results replicate the previously reported partial correlation networks of Faelens et al. (2019), who found that social comparison and self-esteem obtained a central role in linking Facebook use and indicators of psychopathology. Here, it is possible that Facebook use is related to negative affect due to its link with social comparison, self-esteem and RNT, where Facebook use increases the likelihood of social comparison, which is related to more co-occurring RNT and lower self-esteem. Vice versa, given the undirected nature of the contemporaneous network, it is also likely that when being in a negative affective state, one is more likely to experience RNT, which together with self-esteem may be related to more social comparison and Facebook use.

We also modeled temporal and contemporaneous Instagram networks to explore the interrelationships between Instagram use and our constructs of interest. When we look at the temporal network, we obtained interrelationships that are strongly in line with the observed temporal Facebook network. However, we also observed some differences between the networks obtained for both SNS, which may be due to the different nature of Facebook and Instagram, and to differential time investment of participants on these networks in the context of the current study (cf. Table 2). In particular, Instagram use did not predict contingent self-esteem, which was rather unexpected. However, in line with the temporal Facebook network, intensity of Instagram use still predicted subsequent social comparison (on Instagram), decreased self-esteem, increased RNT, and negative affect. The fact that none of the included constructs predicted future Instagram use, indicates that it is more likely that Instagram leads to decreases in well-being than the other way around. This is partially in line with the results of Schmuck et al. (2019), who found that intensity of Instagram use negatively predicted future well-being. However, in line with our findings, well-being and self-esteem did not predict future Instagram use. Contrary to our findings, they did not find a direct relationship between Instagram use and future social comparison on SNS. However, this may be due to different study designs. While our ESM study examined the predictive value of Instagram use on social comparison in rather short time frames, Schmuck et al. (2019) examined this effect over a four-month-interval. Next, in accordance with our temporal Facebook network, we also identified several indirect pathways through which Instagram use may impact affect. That is, our findings illustrate the central role of feelings of insecurity and RNT in the relationship between Instagram use and negative affective state. In addition, some indirect pathways are slightly different compared to the context of Facebook.

Similar to the Facebook network, contingent self-esteem predicted an increase in social comparison and a decrease in self-esteem. There were reciprocal relationships between self-esteem and RNT, self-esteem and negative affect, and also between RNT and negative affect. In line with the Facebook network we also did not find any effect of social comparison on feelings of insecurity, RNT or negative affect. Again, it is possible that our current methodology has problems to accurately capture some of these (nonconscious) processes. In addition, whereas we observed a direct relation between feeling insecure and social comparison on Facebook, this relation did not occur in the Instagram network. Instead we observed a direct positive association between RNT and social comparison on Instagram. Moreover, negative affect was negatively related with future social comparison on Instagram. This suggests that people who experience negative emotions at $t-1$ may try to regulate their emotions by comparing themselves less with the strategically presented content at t . Taken together, these findings suggest that there are a lot of similarities but also some minor differences between Facebook and Instagram in some of the temporal relationships linking both SNS to well-being.

Finally, we estimated the contemporaneous Instagram network. First, contrary to previous findings, we did not observe a significant association between intensity of Instagram use and social comparison (e.g., [Sherlock & Wagstaff, 2019](#); [Teo & Collinson, 2019](#)). However, previous studies used self-report measures to assess SNS use which may significantly differ from log data (e.g., [Boase & Ling, 2013](#); [Junco, 2013](#)). Next, we found a negative association between Instagram use and contingent self-esteem, which was rather unexpected. Together with the previously reported finding that Instagram use was unrelated to contingent self-esteem in the temporal network, this finding suggests that Instagram use does not necessarily elicit more fragile self-worth. Possibly, the type of Instagram use plays an important role. [Faelens et al. \(2019, under review\)](#) demonstrated a negative association between active public use of Facebook (referring to activities that enhance direct interactions between users, such as sharing updates and posting photos; [Frison & Eggermont, 2015](#)) and self-reported contingent self-esteem. Since the main focus of Instagram is on the posting and sharing of pictures, it is likely that Instagram lends itself more to active public use than Facebook. As such, the obtained time logs of Instagram use may reflect SNS use in a more active public way than is the case for Facebook use in the current study, which may explain the presence of this edge in the contemporaneous network of Instagram use and the absence of a similar edge in the corresponding Facebook network. However, since we rely on broad log data that did not distinguish between different patterns of Instagram use, future research is needed to examine this post-hoc explanation.

Next, in line with the contemporaneous network of Facebook use, social comparison on Instagram was related to feeling more insecure, higher contingent self-esteem and higher RNT, which were all positively connected with each other. Moreover, both feeling insecure and RNT were positively related with negative affect. These associations are consistent with previous studies which found that comparison on Instagram was associated with lower levels of self-esteem, higher contingent self-worth, and higher levels of rumination ([Meier & Schäfer, 2018](#); [Stapleton et al., 2017](#); [Teo & Collinson, 2019](#)). Furthermore, [Meier & Schäfer \(2018\)](#) observed a negative link between self-esteem and negative affect. Furthermore, [Hoorelbeke et al. \(2016\)](#) found a positive relation between RNT and fluctuations in negative affect, and vice versa.

To our knowledge, the current study is the first prospective study that modeled the dynamics between Facebook/Instagram use and well-being, while using ESM and log data. Nonetheless, this study is not without limitations. First, sampling biases may have occurred due to the fact that (1) we recruited participants via Facebook groups of students at Ghent University and Facebook/Instagram advertising (e.g., we may have recruited more heavy users), and (2) we could only include Android users due to the logging software (e.g., Android users have

lower SES than iPhone users; [Schmall, 2018](#)). Therefore, our results may not be generalizable to the general population of young adults aged 18–35 years.

Second, previous studies illustrated that different types of SNS usage may be differentially related to well-being outcomes. Specifically, while passive consumption of content of other users seems to decrease well-being, (private) interactions with our connections seem to increase well-being (e.g., [Frison & Eggermont, 2015](#); [Frison & Eggermont, 2017](#); [Verduyn, 2017](#)). However, due to the use of log data, we were not able to make this distinction. Monitoring software logs time investment on SNS and does not store what participants do within the applications in order to respect their privacy. Nevertheless, self-report items do not accurately capture SNS use, therefore monitoring software seems to be the best option as to date (e.g., [Boase & Ling, 2013](#); [Junco, 2013](#)). Third, although ESM-methodology increases the ecological validity of a study, it has the disadvantage that only a limited amount of items or variables can be included in the study ([Hektner et al., 2007](#)). Consequently, our constructs are measured using single-items measures, where the psychometric are less well-established compared to widely used questionnaires. In this context, the use of a pilot study and focus group during the phase of development of the ESM-items forms a key strength of this study.

Fourth, since the goal of the current study was to examine when and how a negative relationship between SNS use and well-being is observed, we only included key constructs that have been supported by previous research ([Faelens et al., 2019](#); [Verduyn et al., 2017](#); [Vogel et al., 2014](#)). Nonetheless, we may have overlooked other important variables. Again, due to the nature of ESM procedures, only a limited number of variables can be included.

Fifth, previous research suggested that motivations of SNS use may play an important role in the relationship between SNS intensity and mental health outcomes. However, in the current study, we did not take this factor into account. Consequently, in order to extend the current research findings, future studies should include participants' motivations of SNS use.

Sixth, the statistical approach used operates under the assumption of a multivariate normal distribution and stationarity of data. Although the assumption of stationarity was met, in line with previous studies some of our variables showed right-skew or kurtosis ([Aalbers et al., 2019](#)). To date it is unclear to what extent the statistical analyses we relied on are robust against such violations. In line with previous work in this area using a similar statistical approach ([Aalbers et al., 2019](#)), we conducted a sensitivity analysis using log-transformed variables. This yielded similar temporal and contemporaneous network models. Relevant discrepancies between main and sensitivity analysis are discussed in supplemental material.

Finally, recent innovations made it possible to evaluate the stability and accuracy of cross-sectional network models. Unfortunately, these methods are not yet available for the two-step multilevel VAR models presented in our manuscript.

5. Conclusion

The current study set out to model the dynamic relations between SNS use and key psychological mechanisms that are proposed to influence mental health. In particular, we logged Facebook and Instagram use, and modeled the relation between both constructs, self-reported social comparison, self-esteem, RNT, and fluctuations in negative affect. Importantly, our findings suggest that: (1) both Facebook and Instagram use predict increased negative affect, and (2) self-esteem and RNT appear to be important intervening constructs in these relationships. Future longitudinal and experimental studies are needed to further clarify the complex relation between SNS use and wellbeing.

Credit statement

Lien Faelens developed the study concept and study design under the supervision of Kristof Hoorelbeke, Ernst Koster and Rudi De Raedt. Kristof Hoorelbeke and Kyle Van Gaeveren performed the data analysis and interpretation. Lien Faelens drafted the introduction, method and discussion section. Kristof Hoorelbeke drafted the data-analyses and results section. Bart Soenens, Lieven De Marez, Rudi De Raedt and Ernst Koster provided critical revision. All authors approved the final version of the manuscript for submission.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.chb.2020.106510>.

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