The effects of mindfulness and positive fantasizing on rumination and depression: A network perspective

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In the past decade, network analysis has gained traction in the field of psychopathology. Major Depressive Disorder (MDD) has been one of its main research targets. In this study, we aimed to extend existing research in several ways. First, unlike most current research, which is concerned primarily with contemporaneous associations between symptoms, this study utilizes momentary assessment data to investigate causal connections between symptoms. Second, this study includes a control group, the lack of which is a common limitation of current network studies. Third, this study focuses on the role of rumination – a critical feature of MDD that has been largely overlooked in network studies. We first compare the network of participants in remission from MDD (rMDD) with that of a healthy control group. Next, we show the respective effects of a mindfulness and a positive fantasizing intervention on the rMDD network. The results suggest that networks of people in remission from MDD are more densely connected than those of their healthy counterparts. Furthermore, the mindfulness intervention appears more effective in weakening symptom-to-symptom connections than the fantasizing intervention. However, permutation testing points towards potential stability issues of the networks.

Keywords: Major Depressive Disorder, rumination, network analysis, experience sampling, mindfulness

Discussion

This thesis aimed to investigate depression from a network perspective. In particular, two main research questions were defined. The first question was about how the networks of symptoms differ between individuals in remission from Major Depressive Disorder (rMDD) and healthy controls (HC). The second question was about the effect two interventions – namely, mindfulness and positive fantasizing – have on the rMDD network. We created a hypothesis network (see Figure 1) and broke our research questions into more concrete subquestions (see Table 1). These were used to guide our analyses and are used to inform the discussion of the results we obtained from mixed-effects modeling and network analysis on data collected via the Experience Sampling Method (ESM). In this section, we will first discuss the results of the analyses and what they might imply for our research questions. Next, the limitations of the study are addressed. Finally, possible avenues for future research are explored.

Findings

We started the analysis by investigating the extent to which the variability of the data is explained by within- and between-subject effects. The intraclass correlation coefficients for *ruminating*, negative affect (*NA*), and positive affect (*PA*) indicated that both types of effects could account for about half of the variability observed in either variable. It was clear, therefore, that mixed-effects methods would have to be employed. Multi-level vector autoregressive network models (mlVAR) were chosen, as a result. However, the current state-of-the-art network analysis methods are exploratory in nature, meaning that they should not be the sole tool one relies on to test hypotheses. Consequently, Generalized Additive Mixed Models (GAMM) were created to supplement the network analysis results and put them on a firmer footing. The combination of GAMM and mlVAR was used to answer the two research questions, which we will now discuss in turn.

Group differences at baseline

The first research question concerned network differences between the rMDD and the HC group. We predicted that the rMDD group would indicate significantly higher levels of rumination and negative affect, while reporting lower levels of positive affect than the HC group at baseline. The hypotheses could partially be confirmed. Both the initial linear mixed-effects models as well as the (nonlinear) GAMMs agreed that being part of the rMDD group was associated with reporting more rumination and negative affect. These effects were both small. This is not surprising given that the subjects in the rMDD group are in a state of remission, rather than full-blown depression. The models disagreed on the effect of the mental health status on positive affect, however. While the linear mixed-effects model supported our hypothesis, the GAMM rejected it.

Figure 1 shows our hypothesis network for the rMDD group. The square elements are the nodes and the thickness of their borders reflects their expected centrality. Arrows in the network depict directed relationships. Green indicates a positive, red a negative association. For stability reasons, we could not include the nodes *sleep quality* and *time spent in company* in the actual networks. Before we discuss the results, a caveat must be mentioned: while the individual networks were reasonably stable, with generally at least half of a network's edges and many nodes' centrality values being statistically significant, the network comparison tests hardly found any statistically significant differences between them. Our first hypothesis concerning the networks was that the HC networks would be less strongly connected overall (i.e., posses lower global strength). Additionally, we expected the negative affect measures to have weaker connectivity among themselves in the HC networks. What we actually found was that the rMDD group's temporal network is more strongly connected globally and locally for the negative affect measures than the HC group's, whereas the opposite is true for the contemporaneous network. While this may well be an artifact of the multi-level vector autoregression model, which creates the contemporaneous networks from the residuals of the temporal networks, it might also be indicative of a diminished ability to get out of a given mental frame of individuals with depressive tendencies. That is, while at any given moment negative emotions tend to arise together in all individuals, they are more likely to sustain themselves and each other over time in individuals with depression. *Rumination* may play a role in this, given that it both significantly influenced and was significantly influenced by *sadness* in the temporal rMDD but not the HC network. Concerning *rumination*, we hypothesized that it would be more central and more strongly connected with both positive and negative affect in the rMDD networks than the HC networks. This is confirmed by the analysis (or at least hinted at given the lack of significance). In general, *rumination* has stronger absolute edge weights in the rMDD networks compared to the HC networks. It is, moreover, more strongly connected with both affect measures. This underpins *rumination*'s stipulated important role in depression and is another small piece of evidence that rumination is a promising target for interventions.

A commonality of the two temporal networks was the importance of *wakefulness*. In both networks, *wakefulness* was the node that impacted other nodes most strongly from one measurement to the next. Interestingly, while the node exerted its influence primarily on the other positive affect measures in the HC network, it mainly decreased negative affect measures (i.e., *irritation* and *sadness*), *distraction* and *event unpleasantness*) in the rMDD network. Alongside *wakefulness*, *energy* was also consistently a highly central node in the temporal and contemporaneous networks, significantly influencing several other nodes. Given that a lack of energy, or fatigue, is one of the criteria for the diagnosis of MDD, the strong influence of both *wakeful* and *energy* is unsurprising. High levels of energy may act as a protective factor, while lower levels may be a significant risk factor for developing or slipping back into depression. Zooming into the positive affect measures, we find that the two mental health status groups share almost identical connection strengths contemporaneous networks. In contrast, the positive affect measures are more densely connected in the HC group's temporal network than the rMDD group's. This could indicate that positive emotional states tend to be more short-lived in people with depression. In addition, the affect measures seem to interact differently with one another depending on the mental health status group. The GAMM results indicated that at lower levels of positive affect, individuals in the rMDD group tended to report higher levels of negative affect. By contrast, no such interaction between positive and negative affect was found for the HC participants.

Intervention effects

In answering our second research question concerning the effects of the mindfulness and the positive fantasizing intervention on the rMDD network, we followed the same basic steps as for the first research question. Thus, we started by investigating how the mental health status interacted with the other variables. We hypothesised that the mindfulness intervention would result in significantly less rumination than the fantasizing condition, whereas the fantasizing intervention would lead to significantly higher positive affect than the mindfulness condition. Even though we also predicted that the positive fantasizing training would more directly reduce the experience of negative affect, we actually did not expect to find significantly lower levels of negative affect in that condition than the mindfulness condition. This is because we believed mindfulness training would significantly reduce rumination, which was expected to have a strong bi-directional relationship with negative affect, ultimately leading to a comparable effect on negative affect of both interventions. Regarding rumination, the GAMM confirmed the hypothesis: on average, the participants in the fantasizing condition reported more rumination than the ones in the mindfulness condition. The effect is small but independent of mental health status, pointing toward the potential of even a fairly minor mindfulness practice to help individuals, whether depressed or not, to disengage from repetitive, negative thinking. Conversely, as Figure **??** shows the reported levels of rumination are neither decreasing nor significantly different from the baseline average at any point in time during the intervention period. That is true for either intervention. Turning to positive affect, we find that positive fantasizing is indeed associated with greater increases in positive affect than mindfulness training. Again, the effect is small and and some of it is cancelled out for healthy individuals receiving the fantasizing

training. Nonetheless, if the primary goal is to increase positive affect, positive fantasizing appears to be a more promising route than mindfulness. As expected, the impact of the interventions on negative affect is not as easily discernible. While participants in the fantasizing condition indicated significantly greater increases in negative affect than the ones in the mindfulness condition, the interaction between the HC group and fantasizing led to significantly decreased levels of negative affect. Given this result, it may be the case that the HC group is more susceptible to the negative affect reducing effects of the positive fantasizing intervention than the rMDD group. Neither intervention changed the relationship between positive and negative affect as Figure 8 shows. However, since positive affect is greater in the fantasizing than the mindfulness condition for almost all levels of negative affect, it provides further evidence that positive fantasizing is more effective in increasing positive affect.

We further hypothesized that both interventions would generally move the rMDD networks to more closely resemble the HC networks. For the mindfulness condition specifically, we expected the *rumination* node significantly decreasing in strength, and a significant reduction in the weight for the edge connecting *rumination* and *negative affect*, ultimately also decreasing *negative affect*'s centrality. Unfortunately, neither the baseline nor the peri-intervention temporal network were stable. As a consequence, we only refer to the contemporaneous networks here. Going counter to our predictions, both *rumination* and *negative affect* actually appear to have gained in centrality from the baseline to the peri-intervention period. In addition, the level of *distraction* increased. However, again, no significant differences were actually found.

For the fantasizing condition primarily expected the *positive affect* node increasing in strength, which could in turn lead to reductions in *negative affect* and *rumination*. Our hypotheses could again not be confirmed. *Positive affect* actually lost in strength in the peri-intervention period when viewed across both the temporal and the contemporaneous networks. *Rumination* and *negative affect* both increased or stayed approximately level. This could be an expression of a propensity to slowly drift towards a depressed state in individuals in remission from MDD.

Limitations

There are a number of limitations that need to be addressed. The biggest one has already been mentioned previously: the network comparison tests hardly showed any significant differences, calling into question the inferences we drew from our results, however tentatively phrased. One reason for this might have been a lack of statistical power. Network analysis methods generally require plentiful data, probably more than we had at our disposal. To alleviate this issue to some extent we combined both blocks of the experiment, potentially confounding some effects. Even though there was a wash-out period of at least one month between the blocks, subjects that had already received one intervention in the first block were regarded as independent entities when they received the other intervention in the second block. Another possible reason for the lack of significant differences discovered was the nature of the comparison tests. There is no generally agreed on method for testing network differences for temporal networks in general and for networks based on mlVAR, in particular. Consequently, for this study we implemented our own approach based on permutation testing. The suitability of the approach was not extensively tested beforehand.

Future Research

In general, at least the second half of this study, that investigated the effects of mindfulness and positive fantasizing training on a network of symptoms in individuals in remission from depression, should ideally be replicated with more participants. To better understand the role of rumination in depression, moreover, it may also be useful to run this study design but use the actual symptoms of depression. This would also make comparing the results with existing studies more feasible.

In working on this study it became apparent that, while network analysis provides a promising avenue to refining our understanding of psychopathology, much research, especially on temporal networks, is still necessary. Whereas there are several algorithms to choose for contemporaneous networks, the choices for temporal networks are more limited. Moreover, while there is a best-practice approach both to stability testing an individual contemporaneous networks and to compare two contemporaneous networks with each other, no such best-practices are available in the realm of temporal networks. This likely scares off many researchers from investigating psychopathology from this angle. A potential alternative for the permutation-based stability analysis used in this study, might be a cross-validation scheme.

Conclusion

This study was concerned with investigating depression and rumination from a network perspective. In particular, it had two main aims. The first aim was to determine how the networks of symptoms of individuals in remission from depression differ from those of individuals without any mental afflictions. The results largely agreed with what we expected. The network of the depressed individuals was more densely connected, especially temporally, and rumination played a more central role in it. The second aim was to investigate the effects mindfulness and positive fantasizing practice would have on such networks, respectively. The mixed-effects models indicated that rumination was more effectively lowered by mindfulness, whereas positive affect was increased more

by positive fantasizing. Unfortunately, we lacked statistical power to extract meaningful networks for either intervention. In general, it also became apparent that much research on temporal network analysis in psychopathology is still needed.

In conclusion, while we likely had too few participants to extract meaningful differences between networks, the results of the study largely appear consistent with previous findings and our hypotheses.

Table 1
Research questions broken down into concrete questions and associated measurements. PA = Positive Affect; NA = Negative Affect.

Subquestion	Measurement
A How does the mental health status group interact with the variables?	Mixed-effects models
B How are different variables related?	Mixed-effects models, edge weights
C What are the most central symptoms?	Centrality measures
D How central is rumination and what associations does it have?	Centrality measures, edge weights
E How densely connected is the network overall?	Global strength
F How strongly are PA measures interconnected?	Local strength
G How strongly are NA measures interconnected?	Local strength

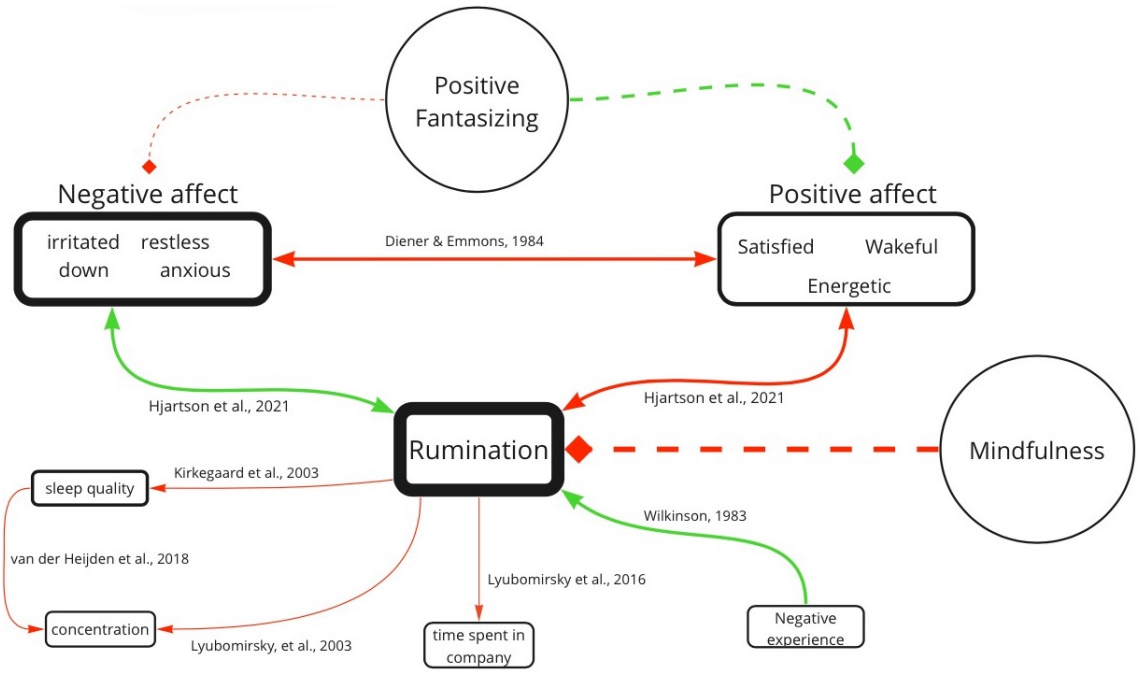

Figure 1
Hypothesis network [will try and make it prettier...].

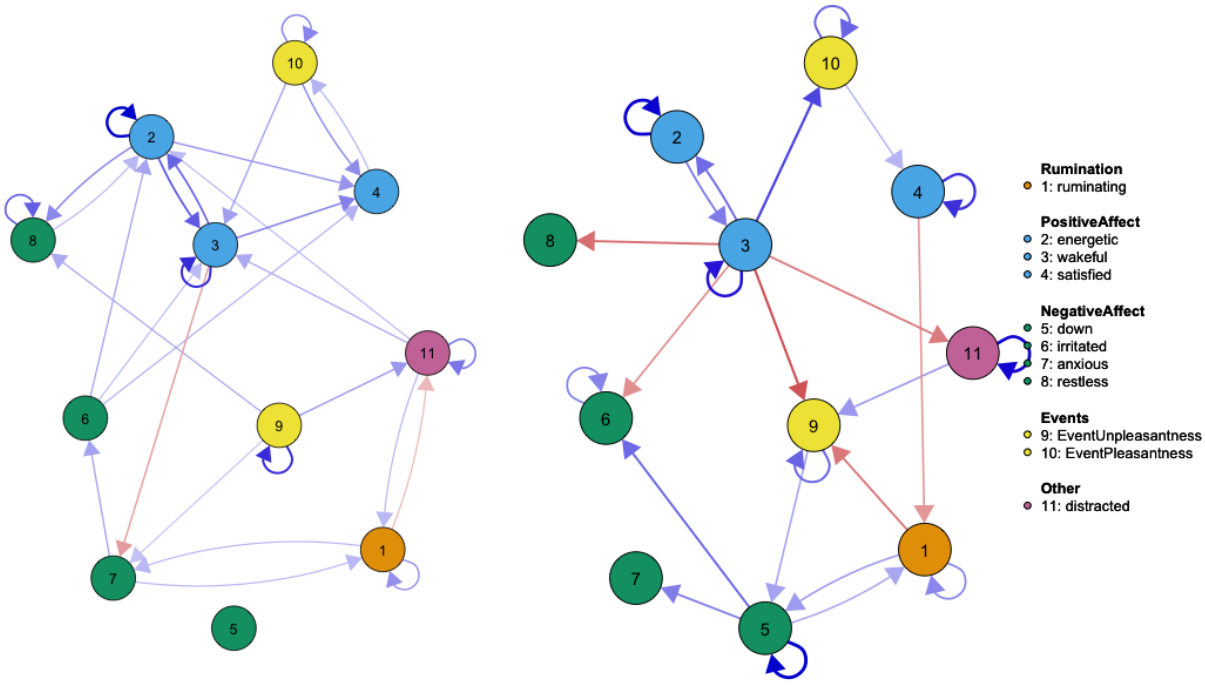

Figure 2
Temporal networks at baseline. Left: HC group; right: rMDD group.

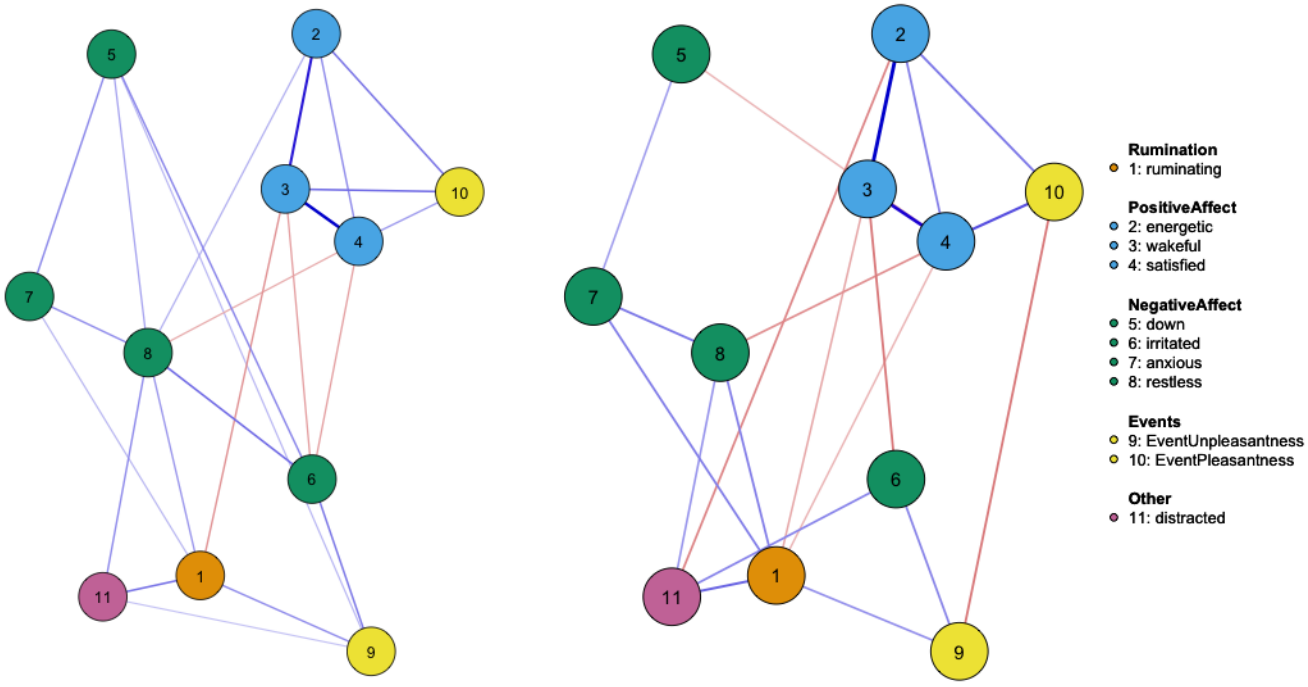

Figure 3
Contemporaneous networks at baseline. Left: HC group; right: rMDD group.

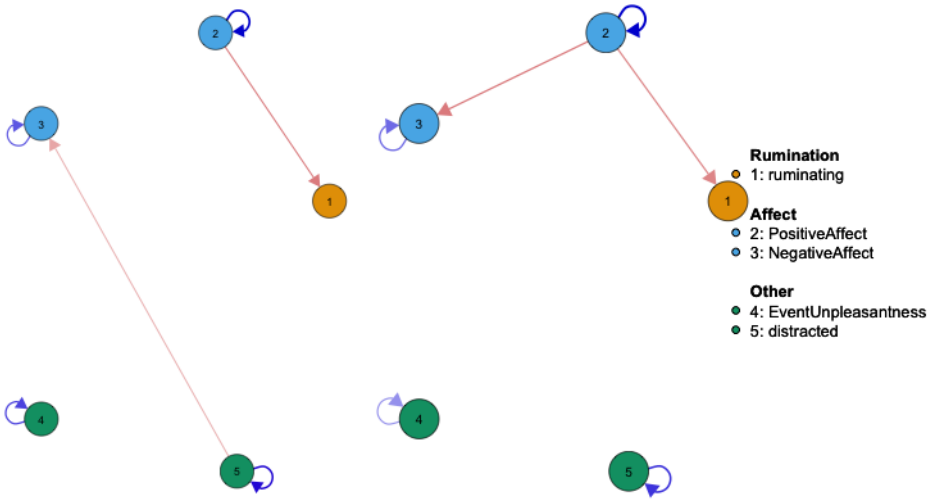

Figure 4
Temporal networks of the rMDD group receiving mindfulness intervention. Left: baseline; right: peri-intervention.

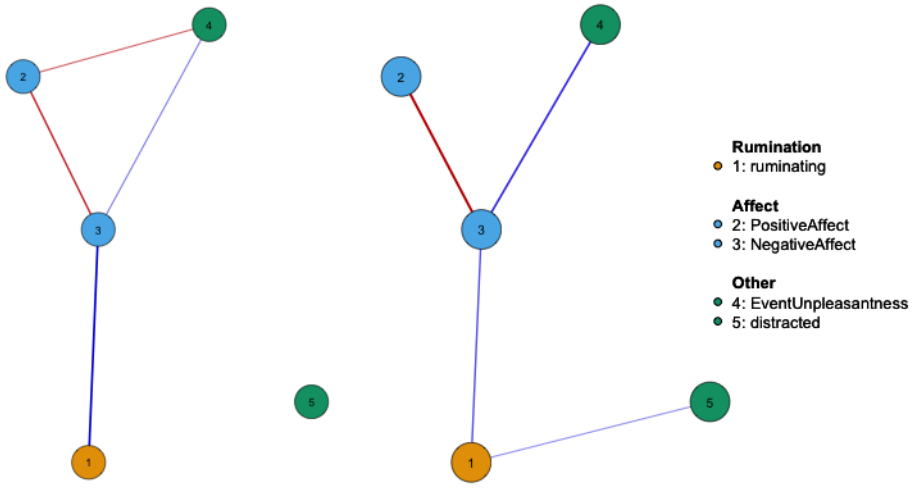

Figure 5
Contemporaneous networks of the rMDD group receiving mindfulness intervention. Left: baseline; right: peri-intervention.

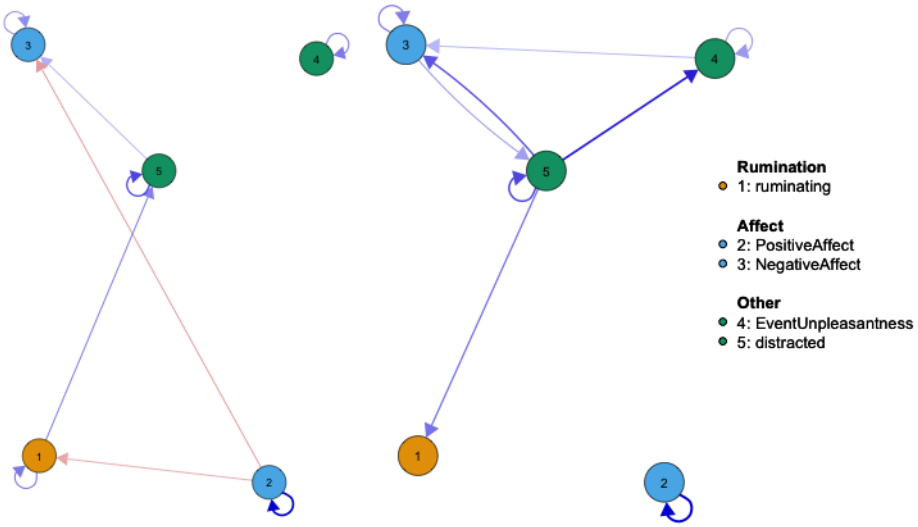

Figure 6
Temporal networks of the rMDD group receiving positive fantasizing intervention. Left: baseline; right: peri-intervention.

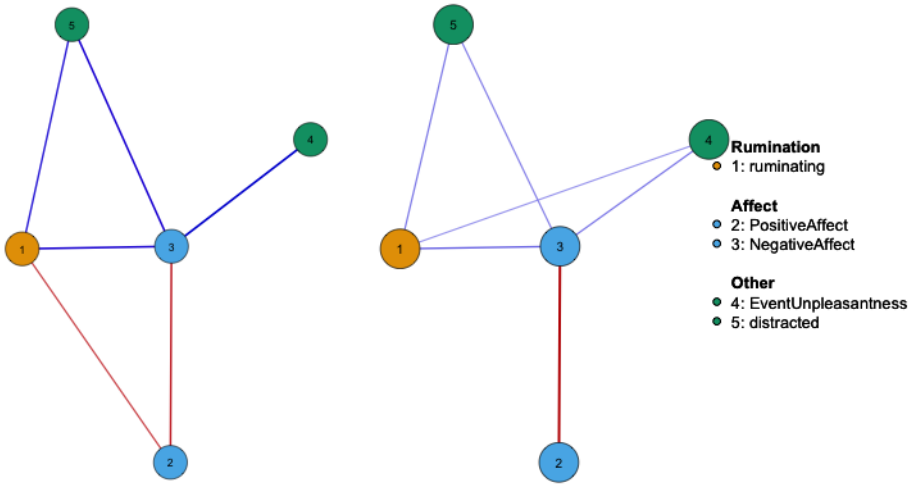

Figure 7
Contemporaneous networks of the rMDD group receiving positive fantasizing intervention. Left: baseline; right: peri-intervention.

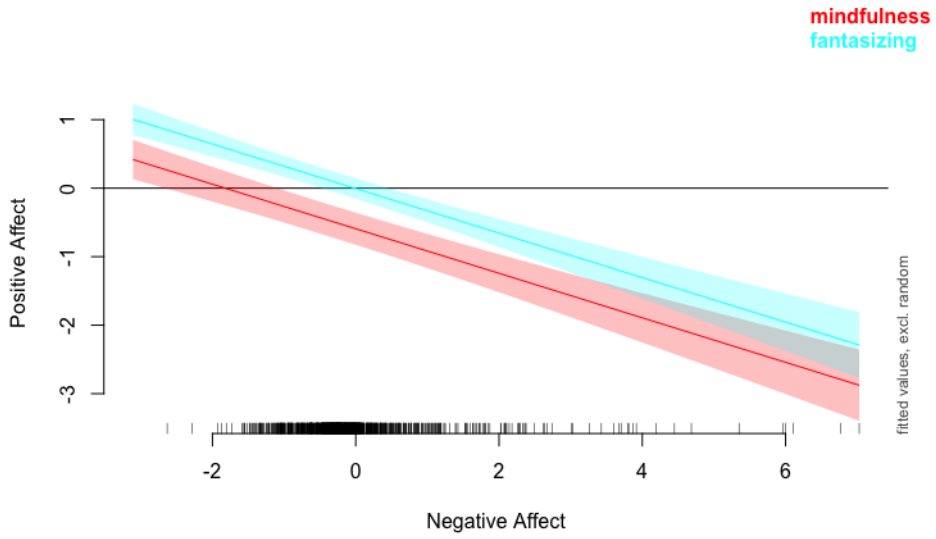
mindfulness
fantasizing
Positive Affect
1
0
-1
-2
-3
-2
0
2
4
6
Negative Affect
fitted values, excl. random

Figure 8

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