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# Reciprocal Associations Between Positive Emotions and Motivation in Daily Life: Network Analyses in Anhedonic Individuals and Healthy Controls

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Anhedonia reflects a dysfunction in the reward system, which can be manifested in an inability to enjoy pleasurable situations (i.e., lack of positive emotions), but also by a lack of motivation to engage in pleasurable activities (i.e., lack of motivation). Little is known about the interrelations between positive emotions and motivation in daily life, and whether these associations are altered in anhedonic individuals. In the present study, we used a network approach to explore the reciprocal, lagged associations between positive emotions and motivation in anhedonic individuals ( $N = 66$ ) and controls ( $N = 68$ ). Participants (aged between 18 and 24 years) filled out momentary assessments of affect 3 times per day for 30 consecutive days. Our results showed that (a) anhedonic individuals and controls had similar moment-to-moment transfer of positive emotions; (b) in the anhedonic network feeling cheerful was the node with the highest outstrength, both within this group and compared with the control group; (c) feeling relaxed had the highest outstrength in the control network, and (d) anhedonic individuals had stronger pathways from positive emotions to motivation than controls. Taken together, our findings suggest that low levels of positive emotions lead to decreased motivation in the anhedonic group, which could instigate a negative spiral of low pleasure and low motivation. On a more positive note, we showed that cheerfulness had the highest outstrength in the network of anhedonic participants. Hence, interventions may focus on increasing cheerfulness in anhedonic individuals, as this will likely have the greatest impact on other positive emotions and motivations.

*Keywords:* anhedonia, network analyses, Experience Sampling Method, positive emotions, motivation

The experience of positive emotions is imperative for mental health and happiness (Fredrickson, 1998). The importance of positive emotions is highlighted by their potential to buffer the effects of negative emotions (Fredrickson & Levenson, 1998; Fredrickson, Mancuso, Branigan, & Tugade, 2000; Geschwind et al., 2010). Further, being able to sustain high levels of positive emotions over time is a characteristic of healthy individuals, and research has indicated that high moment-to-moment transfer of positive emotions is an important buffer against depression (Höhn et al., 2013).

Studies that address maintenance of positive emotions have mainly used composite measures of positive emotions (Houben, Van Den Noortgate, & Kuppens, 2015). However, specific positive emotions may affect each other differentially over time, creating complex patterns of interrelations (Bringmann et al., 2013; Pe et al., 2015). Exploring the differential associations among positive emotions over time can provide more insight in which emotions are particularly important for sustaining high levels of positive emotions. A promising way to explore these associations is to create a network of moment-to-moment associations between emotions. Some studies have explored reciprocal associations between positive and negative emotions in healthy individuals compared with individuals with different types of psychopathology (e.g., Bringmann et al., 2013; Pe et al., 2015; Wigman et al., 2015), but no studies have yet examined a network of positive emotions exclusively.

Gable and colleagues (Gable & Harmon-Jones, 2010; Harmon-Jones, Price, & Gable, 2012) argued that positive emotions can be divided into high approach emotions that directly elicit goal-directed action (e.g., enthusiasm, interest) and low approach emotions that do not (e.g., joy, content, and feeling at ease). However, even though low approach emotions may not lead to goal-directed action directly, they will create the desire to savor current experiences, which could lead to active behavior later on (Fredrickson, 1998). Hence, both low and high approach positive emotions may eventually spark individuals' motivation to go out and participate

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in pleasurable activities (see also Fredrickson, 1998, 2001). In turn, individuals are likely to experience more positive situations when they feel motivated and, thus, feeling motivated may trigger both low and high-approach positive emotions. These reciprocal associations may result in feedback loops between positive emotions and motivation.

To our knowledge, only one study has tried to disentangle the dynamic associations between positive emotions and motivation, by examining differences in effort expenditure between depressed and nondepressed individuals (Sherdell, Waugh, & Gotlib, 2012). Effort expenditure was operationalized as the extent to which participants were willing to view humorous cartoons in relation to the extent to which they enjoyed these humorous cartoons. In healthy individuals, liking and motivation were associated (Sherdell et al., 2012), that is, when participants liked a cartoon, they were more likely to exert effort to be able to view another cartoon. In contrast, in the depressed group, these two aspects of reward processing were dissociated. This lack of association between positive emotions and motivation in depressed individuals is an indication of a dysfunctional reward system. Indeed, depression is often characterized by a reduced hedonic capacity as well as a reduced ability to modulate behavior as a function of rewards, particularly in the presence of anhedonia (Vrieze et al., 2013).

Anhedonia is one of the two core symptoms of depression (American Psychiatric Association, 2013) and reflects impairments in enjoying positive situations (i.e., loss of pleasure) as well as impairments in motivation (i.e., loss of interest; Berridge, Robinson, & Aldridge, 2009; Treadway & Zald, 2011). Research has shown that anhedonia is associated with lower levels of positive emotions and a lack of motivation to engage in pleasurable activities (Berridge et al., 2009), yet little is known about the interrelations between positive emotions in anhedonic individuals. In summary, it remains unclear whether anhedonic individuals differ from healthy individuals in the extent to which (a) positive emotions are sustained over time, (b) positive emotions affect each other over time, and (c) positive emotions and motivation are reciprocally associated. In the present study, we explored reciprocal (i.e., bidirectional), lagged associations between positive emotions and motivation in a network model. Specifically, we aimed to examine (a) whether the centrality (i.e., instrength and outstrength) of positive emotions and motivation in the networks of anhedonic versus controls differed; and (b) whether the instrength and outstrength specifically for the paths from positive emotions to motivation and from motivation to positive emotions differed between groups. We chose three positive emotions that differ in the level of approach-orientation: relaxed for low approach, cheerful for medium approach,<sup>1</sup> and interested for high approach. Motivation was defined as feeling determined and not sluggish. Please note that motivation implies a high level of approach-orientation too. The main difference between the positive emotions and motivation measures is that the latter assessed directly how motivated the participants felt (i.e., determined or sluggish), while the positive emotion measures did not, but may elicit active (approach) behavior, as explained earlier. As loss of pleasure is central to the experience of anhedonia, we included pleasure in the network as well.

## Method

### Participants

The present study was part of the larger “No fun no glory” project, which consisted of two parts: a large online screening survey and a period with momentary assessments. From the large screening survey among 2,937 young adults aged between 18 and 24 years, we selected individuals with persistent anhedonia, defined as low (i.e., below the 25th percentile) levels of pleasure on a general pleasure item from the Domains of Pleasure Scale (DOPS; Masselink et al., n.d.), a perceived pleasure level that was less than what was considered normal, and a loss of pleasure that persisted for more than 2 months. Exclusion criteria for participation were inability to keep an electronic diary three times a day, professional treatment for psychiatric problems, use of psychotropic medication, epilepsy, and pregnancy. Further, as data for the present study were part of a larger study that included a skydive intervention, some skydive-related exclusion criteria were used: conditions that obstruct participating in a tandem skydive (i.e., loose prostheses, height of more than 2 m, weight of more than 95 kg, inability to raise one’s legs 90 degrees, cardiovascular complaints or problems, and significant visual or hearing impairments); and experience with skydiving, bungee jumping, or base jumping. For a detailed description of the total study, see van Roekel et al. (2016).

Screening of the survey sample yielded a group of 148 individuals who were eligible to participate in the anhedonia group. Of this group, 28 participants no longer adhered to the inclusion criteria when contacted, 22 declined to participate, and 29 did not participate because of other reasons. This resulted in 69 anhedonic individuals that participated in the momentary assessments. For each included participant in the anhedonia group, a control participant was matched on age, educational level, and sex. The control participants had to adhere to the same exclusion criteria, and had to report at least moderately high pleasure levels (i.e., >50th percentile) that were rated as similar or higher compared with what was considered normal for that individual. A total of 114 control group participants were invited to participate by e-mail, of which 1 participant did not meet the inclusion criteria, 21 participants declined to participate, and 23 participants were excluded because of other reasons.

### Procedure

For the screening survey, participants were recruited in the Northern part of the Netherlands through flyers, electronic learning environments, advertisements on social media, and invitations during lectures and classes. Individuals who subscribed on the website (<http://www.nofunnoglorry.nl>) received an e-mail with the

<sup>1</sup> According to Fredrickson (1998, 2001) and Frijda (1987) the experience of joy or cheerfulness elicits a general urge to act, or free activation, which would imply that feeling cheerful is a high approach emotion. However, other studies consider joy and cheerfulness as low-approach emotions (Gable & Harmon-Jones, 2010; Harmon-Jones et al., 2012), which do not necessarily elicit active behavior. In the present study, we conceptualized cheerfulness as a moderate approach emotion, which may elicit approach behavior in some situations.

link to the online questionnaire. Upon completion of the questionnaire, participants received a gift card of 10 euros.

Participants who adhered to the inclusion and exclusion criteria as described above were sent an information letter by e-mail. They had to return a signed consent form to participate in the study. After receiving this form, an introductory meeting was scheduled in the University Medical Center Groningen with one of the team members, during which exclusion criteria were rechecked, study procedures explained, and momentary questionnaires practiced with participants. Within a few days after the introductory meeting, participants started with the momentary questionnaires. They received a text message with the link to the online questionnaire on fixed time points with 6 hr intervals (e.g., 9:00 a.m., 3:00 p.m., and 9:00 p.m.). The timing of the assessment schedule was determined in consultation with the participant. The questionnaire had to be filled out within 2 hr after the first notification. If the questionnaire was not yet completed, reminders were sent after 1 and 1.5 hr. Completion of the questionnaire took about 3 min per assessment.

Participants in the anhedonia group filled out momentary questionnaires for 3 months in the context of an intervention study, but only the first 90 assessments (i.e., during the preintervention month when they were unaware of the intervention allocation), were used in the present study. Before and after this month, participants filled out an online questionnaire. The anhedonic participants received 75 euros for completing at least 80% of the momentary assessments, providing two blood samples (not used in the present study) and completing two online questionnaires. Participants in the control group filled out momentary questionnaires for 1 month only, and received 75 euros compensation for completing at least 80% of momentary assessments and both online questionnaires.

The present study is registered in the Dutch Clinical Trial Register (NTR5498) and was approved by the Medical Ethical Committee from the University Medical Center Groningen (no. 2014/508).

## Materials

**Positive emotions.** Positive emotions were measured at each assessment. Participants rated the extent to which they experienced a range of emotions by moving a slider on a Visual Analogue Scale (VAS), with the anchors *not at all* and *very much*. The position of the slider on the scale was transformed into a score between 0 and 100. We included one item for high approach (I feel interested in the things around me; INT), one item for moderate approach (I feel cheerful; CHE), and one item for low approach (I feel relaxed; REL) in the present study. Further, an item was added to measure the amount of pleasure experienced since the last assessment (I have experienced pleasure; PLE).

**Motivation.** Motivation was assessed with two items, I feel sluggish (SLU) and I feel determined (DET), which were measured on the same VAS scale as used for positive emotions. Sluggish was reversely recoded so that higher scores indicated higher levels of motivation.

## Statistical Analyses

In a first step, we ascertained whether differences in anhedonia between groups remained large enough throughout the 1-month study

period, by checking whether participants met the inclusion criteria for the other group at the monthly assessment at the start and the end of the momentary assessments. Next, we used vector autoregressive (VAR) multilevel models using the Dynamic Structural Equation Modeling Package (DSEM) in Mplus Version 8 (Muthén & Muthén, 1998) to explore the lagged associations between positive emotions (i.e., INT, CHE, REL, and PLE) and motivation (SLU and DET). DSEM incorporates Bayesian estimation with uninformative priors (Asparouhov & Muthén, 2010; Muthén & Asparouhov, 2012), using two Markov Chain Monte Carlo chains. To determine convergence of the chains, the potential scale reduction (PSR) factor is used. The default cut-off for convergence in Mplus is PSR <1.1, but smaller cut-offs have been suggested as well (e.g., <1.05, <1.02; see Brown, 2015; Hoofs, van de Schoot, Jansen, & Kant, 2017). In line with recommendations and to ensure convergence of the chains, we increased the number of iterations to at least 20,000 to check whether the PSR remained stably below 1.02.

To examine whether the instrength and outstrength of positive emotions and motivation differed between anhedonic individuals and controls, we created total networks following Bringmann and colleagues (Bringmann et al., 2013, 2016), the main difference being that we were able to run multivariate models instead of univariate models. In this multivariate model, for each variable, the states at time point *t* were predicted by the lagged (i.e., at *t*-1) states of all other variables, as well as the lagged state of the dependent variable itself (i.e., an autoregressive component). For example, CHE at *t* was predicted by SLU at *t*-1, DET at *t*-1, REL at *t*-1, INT at *t*-1, PLE at *t*-1, and CHE at *t*-1. Because it is likely that positive emotions and motivation partly depend on time of day, we controlled for time of day (i.e., morning vs. afternoon vs. evening) by adding dummy variables for afternoon and evening. Separate networks were estimated for the control group and the anhedonic group.

Because a time trend in the variables could lead to spurious correlations (Rovine & Walls, 2006), trends were removed before the analyses by regressing each variable on time for each individual separately.<sup>2</sup> The residuals from these analyses were saved and used as input for the multivariate models. Further, to isolate within-subject effects from between-subjects effects, we calculated within-person standardized coefficients. We added a random effect for each predictor to allow individual differences in the effects.

To visualize the networks for the anhedonia and control group, we used the package qgraph Version 1.4.3 in R (Epskamp, Cramer, Waldorp, Schmittmann, & Borsboom, 2012). We included all paths in the networks, regardless of significance. The main reason for this is that we wanted to use all available information about the different paths to calculate the centrality indices and compare the groups. For example, if one path would be nonsignificant in one group (e.g.,  $p = .055$ ) and significant in the other group ( $p = .045$ ), it is unlikely that these paths differ between groups and, therefore, excluding the nonsignificant path from the network in one group could enlarge differences between groups that may not be real. To compare the networks

<sup>2</sup> To check whether there were differences between groups in time trends, we conducted additional analyses with the different nodes as dependent variables, and time (a variable representing the assessment number) as predictor. As can be seen in Appendix A, Table A1, the only difference found in time trends between groups was that levels of pleasure slightly decreased over time in the anhedonic group, whereas no trend was present in the control group.

between the anhedonia and control group, we calculated two so-called centrality indices, which provide insight into how central a variable (node) is in the network (Epskamp et al., 2012; Opsahl, Agneessens, & Skvoretz, 2010). Outstrength refers to the summed strength of the outgoing paths and is a measure for the extent to which a node affects other nodes. Instrength is a measure for the summed strength of the incoming paths and, thus, indicates the extent to which a node is affected by other nodes. For the total networks, we relied on visual inspection of the differences in centrality indices between the nodes and between the groups. For our second aim, that is, whether the paths from positive emotions to motivation and from motivation to positive emotions differ between the groups, we examined the reciprocal associations between the positive emotion nodes and the motivation nodes, by calculating the instrength and outstrength for each node only for the paths from positive emotions to motivation and vice versa. With the DSEM package in Mplus, it is possible to extract within-person standardized coefficients for all paths in the network, for each individual separately. Based on these individual coefficients, we calculated the instrength and outstrength for the paths from positive emotions to motivation, and vice versa, for each individual separately. In this way, we were able to statistically test whether the instrength and outstrength for these paths significantly differed between the anhedonic and control group, by means of independent sample *t* tests in SPSS.

### Results

First, we checked whether changes had occurred in participants' pleasure levels before and after the month of daily assessments and whether these changes exceeded inclusion criterion levels. We removed four participants from the sample: Three participants in the anhedonic group scored above the 50th percentile at the final monthly assessment and hence adhered to the criterion for the control group, and one individual from the control group scored below the 25th percentile at both monthly assessments and hence adhered to the criterion for the anhedonic group. Hence, our final sample consisted of 66 participants in the anhedonia group and 68 participants in the control group. Of the anhedonic group, the majority experienced at least mild depressive symptoms as measured by the PHQ-9 (minimal symptoms: *N* = 5; mild symptoms: *N* = 26; moderate symptoms: *N* = 19; moderately severe symptoms: *N* = 11; severe symptoms: *N* = 5). Of the control group, the majority of participants experienced minimal depressive symptoms (minimal symptoms: *N* = 45; mild symptoms: *N* = 21; moderate symptoms: *N* = 1; moderately severe symptoms: *N* = 0; severe symptoms: *N* = 1).

### Descriptive Statistics

The descriptive statistics of the anhedonia and control group can be found in Table 1. As a consequence of the matching procedure, age and gender were comparable in both groups. Mean levels of all positive emotions and motivation items were significantly lower in the anhedonia group than the control group.

### Network Models

The network models for the anhedonic individuals and healthy controls are depicted in Figure 1. The model for the anhedonic

group converged after 1,800 iterations, and the model for the control group converged after 1,400 iterations. We increased the number of iterations to 20,000 for both models, to check whether the PSR would remain stably below 1.02. This was the case in both models; after 12,400 iterations in the anhedonic group, and after 8,400 iterations in the control group. This long sequence of stably low PSR values is indicative of model convergence. Both networks show clear links between the nodes, which were mostly positive (see Table 2 for the exact coefficients and significance levels). An interesting find was that higher levels of PLE were associated with lower levels of motivation, that is, higher SLU in both groups and lower DET in the anhedonic group. Further, in both networks, almost all nodes had autoregressive paths with highly similar coefficients. The only exception was INT, for which the autoregressive path was close to zero in the control group.

Although both networks looked highly similar at first sight, visual inspection of the centrality indices (see Figure 2) revealed differences between the groups. For instrength, the main difference between the groups is that the instrength of the motivation nodes SLU and DET is lower in the control group than in the anhedonic group. This indicates that motivation nodes are less strongly affected by the other nodes in the control group, compared with the anhedonic group. In both groups, PLE has the highest instrength, indicating that PLE is most affected by other nodes. For outstrength, CHE had the highest outstrength in the anhedonic group and this outstrength was higher in the anhedonic group compared with the control group. This finding indicates that CHE affects the other nodes in the networks more strongly in the anhedonic group than in the control group. Within the control group, REL had the highest outstrength, and this was slightly higher compared with the anhedonic group.

### Reciprocal Associations Between Positive Emotions and Motivation Nodes

As can be seen in Table 3, both groups significantly differed in the instrength and outstrength of most nodes. The greatest difference between the groups concerns the instrength of DET, and indicates that the anhedonic group reported stronger paths from positive emotions to

Table 1  
Descriptives of Both Samples

Variable	Anhedonia group	Control group	<i>t</i> (df)
<i>N</i>	66	68	
Mean age ( <i>SD</i> )	21.45 (1.96)	21.51 (1.90)	
Male (%)	12 (18.2%)	14 (20.6%)	
Mean ( <i>SD</i> ) level of mental states			
SLU <sup>a</sup>	66.69 (12.17)	77.88 (10.02)	5.81 (132)***
DET	50.58 (10.45)	61.71 (9.14)	6.57 (132)***
CHE	53.89 (10.85)	65.33 (9.75)	6.51 (132)***
INT	52.22 (10.21)	60.73 (9.91)	4.90 (132)***
REL	56.80 (11.58)	64.65 (10.19)	4.17 (132)***
PLE	53.66 (9.96)	62.78 (9.52)	5.42 (132)***

Note. SLU = not sluggish; DET = determined; CHE = cheerful; INT = interested; REL = relaxed; PLE = pleasure.

<sup>a</sup> Please note that sluggish was reverse coded, so that high scores indicate low levels of sluggishness.

\*\*\* *p* < .001.

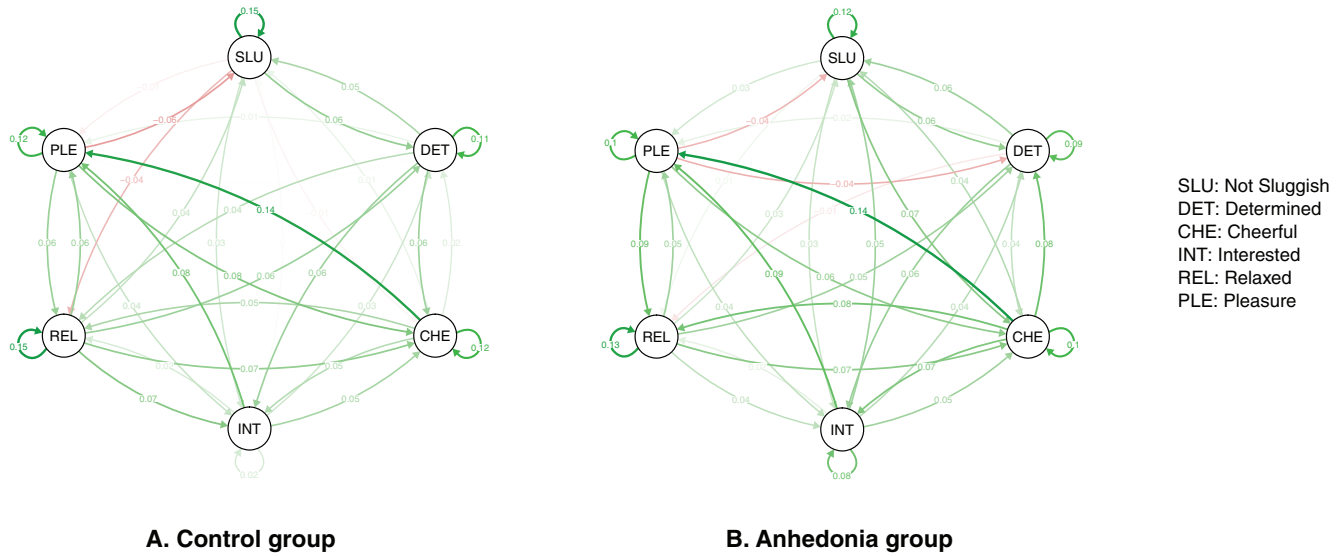


Figure 1. Network plot for the control group (1A) and the anhedonia group (1B).

DET. The outstrength for positive emotions in Table 3, coupled with the network plot (see Figure 1), show that this large instrength of DET in anhedonic individuals was particularly because of strong paths from CHE and INT to DET. For controls, INT and CHE were only weakly associated with DET. With regard to paths going from motivation to positive emotions, the main difference between groups is that the association between motivation nodes and REL were stronger in the control group (i.e., greater instrength for REL, see Table 3). For the outstrength of the motivation nodes, findings were mixed: whereas SLU had a greater outstrength in the anhedonic group, DET had a greater outstrength in the control group.

Post Hoc Analyses

That the paths between positive emotions and motivation were stronger in the anhedonic group than in the control group might reflect that anhedonic individuals have a high potential to benefit from positive emotions, but could also mainly be because of low levels of positive emotions predicting low levels of motivation. The latter would result in a different conclusion than when high levels of positive emotions go together with high levels of motivation. For a

correct interpretation of the findings, we further explored this stronger association in the anhedonic group by zooming in on the strongest paths from positive emotions to motivation: the path from INT to SLU and the path from CHE to DET. We performed a median-split for INT, and calculated correlations between INT at t-1 and SLU at t separately within the INT scores below the median and the INT scores above the median. The same was done for the association between CHE and DET. The results showed that the path from INT to SLU was strongest for below-median levels of INT:  $r = .22$  versus  $r = .03$  for above-median levels. For the path from CHE to DET the correlations were  $r = .30$  for low and  $r = .23$  for high levels of CHE. These findings indicate that the associations between positive emotions and motivation were mainly driven by low levels of positive emotions, and hence that the interpretation that low levels of positive emotions predict low levels of motivation seems more plausible than that highly positive emotions predict high motivation.

Discussion

The main aim of the present study was to examine reciprocal associations between positive emotions and motivation in the daily

Table 2  
Within-Person Standardized Coefficients for All Paths in the Network

Variable	Motivation nodes				Positive emotion nodes							
	SLU		DET		CHE		INT		REL		PLE	
	Control	Anhedonia	Control	Anhedonia	Control	Anhedonia	Control	Anhedonia	Control	Anhedonia	Control	Anhedonia
SLU t-1	<b>.150</b>	<b>.117</b>	<b>.064</b>	<b>.060</b>	-.008	<b>.067</b>	.029	.032	<b>-.043</b>	.010	-.011	.026
DET t-1	<b>.053</b>	<b>.055</b>	<b>.112</b>	<b>.092</b>	<b>.059</b>	.035	<b>.059</b>	<b>.057</b>	<b>.044</b>	-.014	.014	.015
CHE t-1	.014	<b>.043</b>	.020	<b>.081</b>	<b>.115</b>	<b>.105</b>	<b>.046</b>	<b>.071</b>	<b>.052</b>	<b>.077</b>	<b>.142</b>	<b>.142</b>
INT t-1	.005	<b>.054</b>	.030	<b>.041</b>	<b>.054</b>	<b>.053</b>	.024	<b>.080</b>	.024	.016	<b>.084</b>	<b>.088</b>
REL t-1	<b>.036</b>	.029	<b>.060</b>	<b>.053</b>	<b>.066</b>	<b>.066</b>	<b>.074</b>	<b>.037</b>	<b>.153</b>	<b>.130</b>	<b>.062</b>	<b>.054</b>
PLE t-1	<b>-.060</b>	<b>-.042</b>	-.002	<b>-.044</b>	<b>.077</b>	<b>.063</b>	<b>.035</b>	<b>.036</b>	<b>.062</b>	<b>.086</b>	<b>.118</b>	<b>.104</b>

Note. SLU = not sluggish; DET = determined; CHE = cheerful; INT = interested; REL = relaxed; PLE = pleasure. Bold coefficients were significant at  $p < .05$ .

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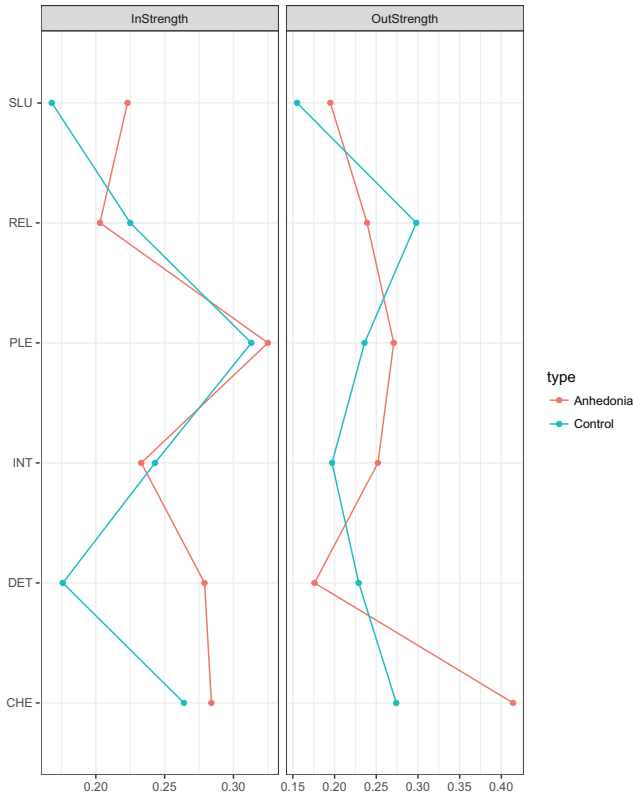


Figure 2. Centrality indices for anhedonia and control group. SLU = not sluggish; REL = relaxed; PLE = pleasure; INT = interested; DET = determined; CHE = cheerful.

lives of anhedonic individuals and matched controls. Our results showed that (a) anhedonic individuals and controls had similar moment-to-moment transfer of positive emotions; (b) in the anhedonic network feeling cheerful, a moderate approach emotion, was the node with the highest outstrength, both within this group and compared with the control group; (c) feeling relaxed, a low approach emotion, had the highest outstrength in the control network;

and (d) anhedonic individuals had stronger pathways from positive emotions to motivation than controls.

When we combine the results from the total networks with the reciprocal associations between positive emotions and motivation, we can conclude that being relaxed played a more important role in the network of controls compared with anhedonics. Relaxed had a greater outstrength in the total network of controls and was more strongly affected by motivation (i.e., greater instrength) and more strongly affected motivation (i.e., greater outstrength) in controls than in anhedonic individuals. This finding is consistent with a study investigating emotion networks in relation to the personality trait neuroticism, typically associated with low positive affect (Ng, 2009), in which the centrality (i.e., betweenness) of being relaxed was higher in individuals with low levels of neuroticism than in highly neurotic individuals (Bringmann et al., 2013). A potential explanation for the higher outstrength of relaxed in our sample could be that compared with anhedonic individuals, being relaxed may be more often accompanied by the urge to savor positive experiences in healthy individuals (Fredrickson, 1998), which may elicit other positive emotions and create the motivation to participate in other pleasant activities. We further showed that being cheerful had the highest outstrength in anhedonic individuals, which was also found in a study on emotion networks in depressed individuals versus healthy controls (Wigman et al., 2015). Considering that these two studies included negative emotions whereas we focused only on positive emotions, these similarities are remarkable and suggest a robust pattern. These findings indicate that individuals with anhedonia have difficulties with eliciting other positive emotions and motivation when they experience low-approach emotions such as feeling relaxed in particular, and less so when they experience medium-approach emotions such as feeling cheerful. Given that cheerfulness had such a high outstrength in anhedonic individuals, interventions to reduce anhedonia might best focus primarily on promoting cheerfulness, as this emotion is likely to spread through the network quickly, and may hence affect other positive emotions and motivation as well. On the other hand, our findings also raise the question what role low-approach emotions such as feeling relaxed play in the development and maintenance of anhedonia: do we need to focus on increasing feeling

Table 3  
Instrength and Outstrength for Hypothesized Paths

Variable	Instrength				Outstrength			
	Control	Anhedonia	<i>t</i>	<i>df</i>	Control	Anhedonia	<i>t</i>	<i>df</i>
<b>Motivation nodes</b>								
SLU	.158	.171	-1.41	110.51	.112	.154	-6.26***	132
DET	.149	.222	-9.98***	132	.188	.136	6.84***	98.18
<b>Positive emotion nodes</b>								
CHE	.074	.103	-6.96***	132	.069	.126	-8.79***	121.13
INT	.098	.092	.87	111.46	.042	.096	-13.59***	101.15
REL	.089	.043	9.39***	132	.098	.084	3.55**	106.21
PLE	.039	.053	-3.04***	124.52	.099	.087	1.41	91.50

Note. SLU = not sluggish; DET = determined; CHE = cheerful; INT = interested; REL = relaxed; PLE = pleasure. Only the paths from PA to motivation and vice versa were included in the calculation of instrength and outstrength. In this way, the instrength represents the extent to which each motivation node was affected by PA nodes, and the extent to which each PA node was predicted by motivation nodes, whereas the outstrength represent the extent to which each motivation node predicted the PA nodes, and vice versa.

\*\*  $p < .01$ . \*\*\*  $p < .001$ .

relaxed as well, and do we need to provide anhedonic individuals with tools to wind down, particularly after they experienced high levels of motivation? Or do anhedonic individuals use their “relax time” differently, for example by not savoring their current experiences? Further research is needed to explore the role of low-approach emotions such as feeling relaxed in anhedonia.

We found that higher levels of experienced pleasure predicted lower levels of motivation both in anhedonic individuals and controls. Possibly, individuals tend to be tired after highly pleasurable events and, therefore, experience lower levels of motivation at the next assessment. The causal chain could also work the other way around: individuals who experience low levels of pleasure may be very motivated to go out and participate in pleasurable activities in the upcoming hours. Further, positive emotions predicted motivation more strongly in the anhedonic individuals than in the control group, whereas no consistent differences were found for the paths from motivation to positive emotions. Post hoc analyses showed that the path from positive emotions to motivation in the anhedonic group should primarily be interpreted as low levels of positive emotions leading to decreased motivation in the anhedonic group, which could lead to a negative spiral of low positive emotions and low motivation. We recommend this differentiation in low and high levels of the independent variable in post hoc analyses for future network studies, as it provides important insights into the driving forces behind the associations in the network, which is important for interpretation of the associations.

Anhedonic individuals were equally able as controls to sustain their level of positive emotions and motivation over time in our study, which is in line with previous research in depressed patients (Peeters, Nicolson, Berkhof, Delespaul, & deVries, 2003; Thompson et al., 2012). Although this could be interpreted as a positive finding, in that anhedonic individuals have no difficulties sustaining positive emotions and motivation over time, there are two important things to keep in mind here. First, we found that anhedonic individuals in general reported lower levels of positive emotions and motivation, and hence these positive autoregressive paths could imply that they remain stuck in these low levels. Second, these autoregressive paths represent the extent to which emotions are carried over to the next assessment, without taking into account environmental circumstances such as positive events. Some researchers interpret high stability in emotions as a negative characteristic, as it may be beneficial to be emotionally reactive to the environment. Whether or not emotional stability represents a risk may depend on the time interval between assessments (Trull, Lane, Koval, & Ebner-Priemer, 2015): whereas a study that used very short time intervals (seconds) found that greater stability in positive emotions predicted the onset of clinical depression 2 years later (Kuppens et al., 2012), another study with larger intervals (90 min on average) found that high stability had a positive prospective effect on wellbeing (Höhn et al., 2013). Possibly, being able to shift in emotions in a very short time frame is indicative of flexible adaptation to a changing environment (Kuppens et al., 2012), which is likely to be beneficial for mental health in the long-term. On the other hand, long-term shifts in emotions may be indicative of emotional instability that is detrimental for mental health in the long run. In the present study, one difference emerged between the control group and the anhedonic group in the autoregressive paths: feelings of interest were not sustained across assessments in the control group. A speculative explanation could be that feeling interested is triggered

more by environmental circumstances than other positive emotions in this group and hence more variable. Further research is needed to test this hypothesis.

## Strengths and Limitations

Our study had many strengths, including high ecological validity as we measured individuals' positive emotions and motivations in real life, a long period of momentary assessments including 90 assessments per individual, and high compliance, as all participants filled out at least 80% of the momentary assessments. Like every study, it had some limitations as well. First, we did not include contextual features in our models, although both positive emotions and motivation are likely affected by external circumstances. Further research could include, for example, occurrence of positive events, activity level, and social context. Second, given that our measures were on average 6 hr apart, we may have missed important fluctuations in positive emotions and motivation that occurred within a shorter timeframe. Because of this relatively large timeframe between assessments, we decided to only include lag 1 associations. Third, the majority of our sample was female, which may limit the generalizability of our findings. Fourth, we aimed to select participants based on the presence of anhedonia and not on the presence of psychiatric disorders. Therefore, our findings are only generalizable to individuals with anhedonia. In the present study, we did not have enough power to further distinguish between psychiatric disorders in the anhedonic group. It would be interesting for further research to explore whether the dynamics of positive emotions and motivation differ between individuals who experience anhedonia in combination with different psychiatric diagnoses (e.g., depression, schizophrenia).

## Conclusion

Taken together, experiencing low levels of pleasure may lead to decreased motivation in anhedonic individuals. As we also found indications that, although less strongly, motivation is predictive of decreased positive emotions later in time, these reciprocal associations may result in a negative spiral of low pleasure and low motivation in anhedonic individuals. On a more positive note, we showed that cheerfulness had the highest outstrength centrality in the network of the anhedonic participants. Given this high outstrength of cheerfulness, interventions could focus on increasing cheerfulness in anhedonic individuals, and so positively affect other positive emotions and motivations.

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(Appendix follows)

## Appendix

### Time Trends

Table A1  
*Time Trends for the Different Nodes*

Variable	Time trend	
	Control	Interaction <sup>a</sup>
SLU	.08 (.01)**	.01 (.02)
DET	.09 (.02)**	-.01 (.02)
CHE	.04 (.01)**	-.02 (.02)
INT	.02 (.01)	-.01 (.01)
REL	.08 (.01)**	-.04 (.02)
PLE	.02 (.01)	-.05 (.02)*

*Note.* SLU = not sluggish; DET = determined; CHE = cheerful; INT = interested; REL = relaxed; PLE = pleasure.

<sup>a</sup> The interaction represents the extent to which the anhedonic group differed in time trend from the control group.

\*  $p < .01$ . \*\*  $p < .001$ .

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