Neural mechanism of basic psychological needs satisfaction based on self-determination theory

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ABSTRACT

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Individuals have basic psychological needs – autonomy, competence, relatedness – that must be satisfied to maintain the overall vitality and psychological well-being. Optimal motivation is critical for maintaining individuals' psychological health. In this way, moving towards an intrinsically motivated state leads individuals to have higher satisfaction with life. The current research expands the previous neuroimaging studies on basic psychological needs support and intrinsic motivation by examining the differences in functional connectivity of individuals with high and low life satisfaction. A total of 83 young adults (mean age =22.9, SD = 2.46) were divided into high satisfaction and low satisfaction with life groups. The overall satisfaction with life, basic psychological needs satisfaction, self-esteem, self-perceived anxiety and depression were measured. The main task consisted of a 5-min resting-state fMRI scan followed by an anatomical scanning of the entire brain. A seed-to-voxel analysis was performed with a CONN Toolbox on Matlab R2018a. The regions of interest were the anterior cingulate cortex (ACC), medial orbitofrontal cortex (mOFC), and nucleus accumbens (NAcc). The two groups showed significant differences in each of the autonomy (t_{81}=4.47, p<0.001), competence (t_{81}=7.28, p<0.001), and relatedness score (t_{81}=3.68, p<0.001). No differences in age and gender was found. There was a significant group-by-autonomy score interaction in mOFC – right occipital cortex connectivity ($P_{FDR} < 0.001$) and a significant interaction effect in NAcc – bilateral frontopolar cortex (FPC) connectivity ($P_{FDR} < 0.001$), and NAcc – bilateral mOFC connectivity ($P_{FDR} = 0.001$). As for the group-by-competence score interaction, the connection between the amygdala and bilateral medial prefrontal cortex was significant ($P_{FDR} = 0.002$). Finally, a significant group-by-relatedness score interaction effect was found in mOFC – left FPC connectivity ($P_{FDR} = 0.002$) and mOFC – left subcallosal ACC connectivity ($P_{FDR} = 0.036$). Also, a significant effect was found in NAcc – bilateral posterior cingulate cortex connectivity ($P_{FDR} < 0.001$) and ACC – bilateral ventromedial prefrontal cortex connectivity ($P_{FDR} = 0.004$). These findings suggest that individuals' perceived life satisfaction affects the relationship between the basic psychological needs support and reward processing in the brain.

Key words: autonomy, competence, relatedness, intrinsic motivation, reward processing, resting-state functional connectivity

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I. INTRODUCTION

The self-determination theory (SDT) posits that individuals have innate needs that have to be met to support the psychological well-being.[1] These innate needs are as follows: autonomy, competence, and relatedness.[2] This theory further notes that the extent to which the three needs are satisfied or frustrated affect the social development and subjective well-being of the individuals. For example, need satisfaction is important for adolescents' well-being in relation to leisure activities.[3] Basic need satisfaction not only modulates the association between life satisfaction and job satisfaction,[4] but also mediates materialism and decreased life satisfaction.[5] In the same study, need satisfaction is also found to be related to gratitude, which in turn affects life satisfaction. Relatedness needs are especially important in fostering self-efficacy, which in turn positively affects academic achievement and life satisfaction[6]. Therefore, previous studies demonstrate that supporting the basic psychological needs is critical for life satisfaction. Considering that individuals with high life satisfaction are related to higher self-esteem, social adjustment and that individuals with low life satisfaction, even without a diagnosis of mental disorder, experience anxiety and depression, there is a need to look at how need frustration and need support affects these individuals separately.

1. Basic psychological needs satisfaction and intrinsic motivation

Previous research has shown this concept in relation to motivation. The most plausible way to explain how individuals have different ways of carrying out the action is by showing whether the act is driven by inner desire or by an external reward. In other words, the intention to carry out an action is on a continuum from autonomous motivation to controlled motivation, where autonomous motivation is driven by one's own willingness to participate in the activity.[7] On the other hand, controlled motivation is driven by the needs to avoid punishment or to gain the desired result.[8] In this way, SDT attempts to explain the intricate ways these two sources of motivation guide human behavior.[2] Much of this underlying concept of basic psychological needs have previously been studied in many different contexts such as in education,[9,10] human resource development,[11] health and medicine,[12,13] psychotherapy,[14] and sports.[15,16]

2. The theoretical basis of basic psychological needs satisfaction

Firstly, autonomy is the need to be an agent in the initiation and regulation of one's behavior. Autonomy satisfaction is the extent to which personal ownership is exhibited, whereas autonomy frustration indicates the taking away of the rights over the self-induced behavior and actions.[2,17] Previous research has shown that autonomy satisfaction is a key factor that consequently affects the level of the other two needs. Next, competence refers to the desire to extend one's abilities and to demonstrate in the social environment.[2] It is specifically related to the need to seek situations that allow individuals to exert skills and abilities and find ways to develop them continuously. Competence satisfaction is demonstrated when one can successfully show one's capabilities in everyday life or at work, whereas dissatisfaction is demonstrated when the abilities to seek for those situations is taken away, or when the individuals perceive their own skills is not being acknowledged in the social environment. Finally, relatedness is the need to be an important agent in social relationships.[2] Relatedness satisfaction is when one perceives that there are meaningful connections with others, whereas relatedness needs are not met when there is a lack of social contact or when one perceives that others do not show care.

Empirical evidence shows that satisfying the above needs is related to an overall heightened sense of well-being, vitality, and psychological flexibility.[2,13] In the education system, programs that foster the satisfaction of the psychological needs are associated with the student's depression level, negative affect, and overall academic achievement.[18] Similarly, in the workplace, supporting the psychological needs, specifically autonomy leads to the internalization of work motivation and positive work outcomes.[19,20] In this manner, work-related basic needs satisfaction scale has also been validated for wide use.[21] On the other hand, the frustration of psychological needs negatively affects psychological well-being. For instance, autonomy controlling teaching is related to maladaptive behavior and disengagement in students and frustrating the needs of employees in the workplace negatively affects their psychological functioning.[22,23]

3. The neurological basis of intrinsic motivation

Although theoretical exploration of the basic psychological needs support and frustration are well-established in the literature, there continues to be a lack of research on finding the neurobiological factors associated with the construct. Recently, there have been preliminary efforts to delineate the neural mechanism of intrinsic motivation based on SDT. The literature primarily focuses on intrinsic motivation in relation to basic psychological need support or frustration. For instance, a recent review proposes two theories regarding the different neural pathways that are implicated in intrinsic motivation.[24] First is related to the dopaminergic signaling within the reward system in the brain. The areas involved are the substantia nigra (SN), nucleus accumbens (NAcc), dorsal striatum, and ventromedial prefrontal cortex (vmPFC) that signal the reward detection and learning.[24,25]

The next mechanism is the dynamic switching between the major networks in the brain for salience detection, attentional control, and self-referential cognition.[24] The salience network includes the anterior insula and dorsal anterior cingulate cortex (ACC), which works to detect important information. Other areas involved are the amygdala, NAcc, SN, and ventral tegmental area (VTA). Previous evidence suggests that this network modulates the two central networks: the default mode network (DMN) and central executive network (CEN).[26] The DMN is activated during self-referential cognitive activity and deactivated during a task-based activity.[27] When intrinsic motivational states are induced, there is an activation in the salience and CEN, which in turn suppresses activity of the DMN.[28] Much of these available evidence uses a task-based experimental set-up by changing the motivational state of the participant through artificially presenting situational conditions that affect the psychological needs of the individual. Based on the evidence, it is speculated that the important regions associated with basic psychological needs satisfaction are the ACC as a center for salience network, the NAcc and medial orbitofrontal cortex (mOFC) as regions for the reward network and the amygdala as a center for emotional control.

Previous studies have only looked into how the difference in life satisfaction affects the brain by examining the effect of psychological intervention.[29,30] In this study, autonomy, competence, and relatedness need satisfaction in individuals with high and low life satisfaction was associated differentially after experiencing the two types of intervention. To date, not much is known about resting-state connectivity of individuals with different life satisfaction and how this relates to a psychological concept. Considering that most of the previous results are based on a task-based experimental set-up, there is a need to figure out the *innate* differences in connectivity based on each of the three constructs of basic psychological needs.

Therefore, the current research plans to examine the relationship between each of autonomy, competence, and relatedness support and the changes in the strength of resting connectivity. The main objective of this research is to find a connection between the theory and physiology in hopes to extend the understanding of SDT from a neurobiological perspective. It is expected that regions involved in intrinsic motivation will be associated with each of the constructs. The sub-measures will be associated with resting connectivity of the salience and reward network and will show different associations among individuals with high and low life satisfaction.

4. Hypothesis

The level of basic psychological needs in individuals with high life satisfaction will be significantly different from individuals with low life satisfaction. The correlation between functional connectivity of the salience network (i.e., the ACC) and the reward network (i.e., the NAcc and mOFC) and each of the autonomy, competence, and relatedness score will be different in individuals with high and low life satisfaction.

II. METHODS

1. Participants

In this study, participants were recruited over the two phases. The respondents' scores on satisfaction with life scale were grouped into four quartiles. In the first phase, 276 participants responded to the screening survey online. Of these participants, 110 participants were in the highest 25% (1^{st} quartile) group and 78 were in the lowest 25% (4^{th} quartile). Twenty-four participants were included in the high life satisfaction (HLS) group and 20 participants were included in the low life satisfaction (LLS) group.

In the second phase, a total of 361 participants responded and 127 participants fell in the highest 25% (1^{st} quartile) group and 90 fell in the lowest 25% (4^{th} quartile) group. Of these participants, 17 were included in the HLS group and 22 were included in the LLS group. Overall, 41 participants were included in the HLS group (20 males, mean age = 22.5 ± 2.3) with the range of total score between 4 and 5. Forty-two participants were included in the LLS group (21 males, mean age = 23.3 ± 2.6) with the range of total score between 1.2 and 3.2. In sum, 83 participants were included in the data analysis.

The exclusion criteria include a history of psychiatric illness, neurological disorders, and metal implants in the body. The Annett's Handedness Questionnaire (12-item scale) was used to screen out individuals who are left-handed.

2. Clinical Measures

A. *Hospital Anxiety and Depression Scale (HADS).* This is a 14-item scale measuring the level of anxiety (7 items) and depression (7 items) in participants, each including four statements in the order of increasing severity.[31] Each of the ratings is summed to generate a total score, where a higher score represents a higher depressive or anxious state.

B. *Rosenberg Self-Esteem Scale.* This is a 10 item scale measured on a 4-point Likert scale (1 = almost never, 4 = very much).[32] A total score is generated and the higher the score, the higher the self-esteem.

C. *Satisfaction with Life Scale.* This is a 5 item scale rated on a 6-point Likert scale (1= almost never, 6 = very much).[33] An average of the responses of the question is taken to generate a score between one and six, and the higher the score, the more satisfied the responder.

D. *Basic Psychological Needs Satisfaction Scale (BPNS).* A modified version of this scale consists of 18 items, rated on a 6-point Likert scale (1 = almost never, 6 = very much) with subscales that each measure autonomy, competence, and relatedness.[1,34] The higher the total score in each subscale represents the higher level of basic psychological needs satisfied.

3. fMRI Parameters

The fMRI task consists of a 5-minute rs-fMRI scan. During this trial, participants were instructed to gaze at a cross sign (+) on the screen connected to the MRI scanner. This was followed up by an anatomical scanning of the brain. The entire session lasted approximately 15 minutes.

Resting state functional magnetic resonance imaging (rs-fMRI) data were acquired on 3.0 T Philips Ingenia scanner using the multiband SENSitivity Encoding (SENSE) sequence, TR = 800 ms, TE = 30 ms, flip angle = 52°, Number of acquisition = 385, Number of slice = 60, Slice order = bottom-up and interleaved, Slice thickness = 2.4 mm, FOV = 216 mm, Image matrix = 96 x 93. Anatomical images were obtained using a 3D T1-weighted fast gradient echo sequence, TR = 9.9 ms, TE = 4.6 ms, flip angle = 8°, Number of slices = 220, Slice thickness = 1 mm, FOV = 224 mm, Image matrix = 224 x 224.

Preprocessing steps were based on Statistical Parametric Mapping 12 (SPM12). After removing 10 dummy scans, the remaining 375 scans were realigned to the first image and corrected for acquisition time differences among slices. Individual anatomical images were co-registered to the mean fMRI image and these were spatially normalized to the Montreal Neurological Institute (MNI) template space and smoothed with a 6-mm full-width at the half-maximum Gaussian kernel. The time series at each voxel were further processed to remove the effects from nuisance parameters. We applied standard temporal preprocessing procedures, including removal of linear components associated with the six rigid-body head motion parameters plus their time derivatives, regression of the mean time series of the white matter and cerebrospinal fluid, removal of the linear trend, and bandpass filtering (0.009-0.08 Hz).

The identified regions of interest (ROI) are based on an automated anatomical labeling atlas 3 (AAL3). The ACC seed was the average of the three parcellations designated by the AAL3 atlas (*ACC_sub, ACC_pre,* and *ACC_sup*). The mOFC seed was designated as the average of the left and right parcellations (*OFCmed_R* and *OFCmed_L*). The NAcc and amygdala were also based on the average of the left and right parcellation of the atlas.

4. Data Analysis

A. *Behavioral Analysis.* To compare the difference in the means of the demographic and clinical variables between the two groups, an independent *t*-test will be used. Bivariate correlation was conducted to examine the relationship between the clinical variables and sub-components of the BPNS. The analysis was conducted to delineate the connections in the brain that specifically relates to the measures of basic psychological needs. The statistical analyses were carried out on SPSS Statistics 25.0.

B. *fMRI Imaging Analysis.* Pre-processing and data analysis were conducted using SPM12 (Welcome Department of Imaging Neuroscience, London, UK) on Matlab R2018a (Mathworks, Natick, Massachusetts, USA). A seed-to-voxel analysis was performed with the CONN Toolbox. A significant connectivity threshold was defined by false discovery rate (FDR) $P_{FDR} < 0.05$ at the cluster level with a cluster-defining threshold of $P < 0.005$. Analysis of covariance (ANCOVA) was conducted to test the differences in the association of the BPNS and functional connectivity between the two groups. The ROIs selected were areas involved in intrinsic motivation based on findings shown in the literature.

III. RESULTS

1. Demographic Information

Independent samples *t*-test and a *chi*-square test were conducted to compare the demographic profile of the HLS and LLS group. Forty-one participants were included in the HLS group (mean age = 22.5 ± 2.3) and 42 participants were included in the LLS group (mean age = 23.3 ± 2.6). There was no significant difference between the mean age of the two groups (t_{81}=-1.35, p = 0.181). Also, the proportion of males and females in each group was not statistically significant ($\chi^2(1, N=83) = 0.01, p = 0.912$). The proportion of males in the HLS and LLS group was 48.8% and 50.0%, respectively.

2. Clinical Assessment

Independent samples t-test was conducted to compare the clinical measures of the HLS and LLS group. The two groups showed significant differences in each of the autonomy (t_{81}=4.47, p<0.001), competence (t_{81}=7.28, p<0.001), and relatedness score (t_{81}=3.68, p<0.001) based on the BPNS. Additionally, a significant group difference was found in the anxiety (t_{81}=-4.52, p<0.001), depression (t_{81}=-5.63, p<0.001), and self-esteem (t_{81}=8.34, p<0.001). Refer to Table 1 for a summary.

Table 1. Demographic and clinical characteristics by life satisfaction group

Variables	HLS (N=41) M (SD)	LLS (N=42) M (SD)	χ^2 /t	*p*
Male (%)	48.8	50.0	0.012	0.912
Age (years)	22.51 (2.28)	23.24 (2.60)	-1.35	0.181
BPNS				
Autonomy	29.90 (3.40)	26.52 (3.49)	4.47	<.001**
Competence	29.29 (3.48)	24.27 (2.72)	7.28	<.001**
Relatedness	31.39 (3.56)	28.62 (3.30)	3.68	<.001**
HADS				
Anxiety	4.29 (2.87)	7.45 (3.47)	-4.52	<.001**
Depression	3.78 (2.67)	7.05 (2.62)	-5.63	<.001**
RSES	34.37 (3.90)	26.98 (4.16)	8.34	<.001**

* *Note.* HLS, High life satisfaction; LLS, Low life satisfaction; M, Mean; SD, Standard Deviation; BPNS, Basic Psychological Needs Satisfaction Scale; HADS, Hospital Anxiety and Depression Scale; RSES, Rosenberg Self-Esteem Scale

3. Correlation Analysis

Bivariate correlation analysis was conducted to examine the relationship between the clinical measures and each of the components of the BPNS (autonomy, competence, and relatedness). In the HLS group, a significant negative correlation was found between the sub-scales of the BPNS and HADS (anxiety and depression). Autonomy score was significantly associated with anxiety (r_{39} = -0.56, p=<0.001), and depression (r_{39} = -0.40, p=0.01). Competence score was also significantly correlated with anxiety (r_{39}= -0.50, p=0.001), and depression (r_{39}= -0.40, p=0.009). Finally, relatedness score was significantly correlated with anxiety (r_{39}= -0.36, p=0.02), and depression (r_{39}= -0.53, p=<0.001). Each of the sub-scale measures of BPNS correlated with another. In the LLS group, only a significant negative correlation between anxiety and autonomy (r_{39}= -0.38, p=0.014) were found. In both groups, self-esteem showed a positive correlation with each of the sub-scales of BPNS. Refer to Table 2 for a full correlation matrix.

Table 2. Correlation matrix for clinical variables and basic psychological needs measure

Scale	1. Auto		2. Com		3. Relat		4. Anx		5. Dep		6. RSES
	HLS	LLS	HLS	LLS	HLS	LLS	HLS	LLS	HLS	LLS	
1. Auto	1.00										
2. Com	.55**	-.01	1.00								
3. Relat	.40**	.00	.57**	.20	1.00						
4. Anx	-.56**	-.38*	-.50**	.23	-.36*	-.08	1.00				
5. Dep	-.40*	-.14	-.40**	-.07	-.53**	-.17	.72**	.35*	1.00		
6. RSES	.65**	.32*	.67**	.02	.73**	.32*	-.60**	-.51**	-.63**	-.43**	1.00

Note. HLS, High life satisfaction; LLS, Low life satisfaction; **Significance at p<.001 *Significance at p<.01. Auto, autonomy; Com, competence; Relat, relatedness; Anx, anxiety; Dep, depression; RSES, Rosenberg Self-Esteem Scale.

4. Imaging Data

To examine significant between-group differences in the association with each of the sub-scales of BPNS, one-way ANCOVA covariate interaction was used for analysis. When comparing the sub-score, the other two sub-scores were included as a controlled covariate. This was to ensure that the effect of the other two scores did not confound the results. There was a significant group-by-autonomy score interaction in the mOFC and right occipital cortex ($P_{FDR} < 0.001$). For sub-cortical regions, there was a significant group-by-autonomy interaction effect in NAcc – bilateral frontopolar cortex (FPC) connectivity ($P_{FDR} < 0.001$) and NAcc – bilateral mOFC connectivity ($P_{FDR} = 0.001$). As for the group-by-competence score interaction, the connection between the amygdala and bilateral medial prefrontal cortex (mPFC) was significant (P_{FDR} = 0.002). Finally, a significant group-by-relatedness score interaction effect in mOFC – left FPC connectivity (P_{FDR} = 0.002), mOFC – right cerebellum connectivity (P_{FDR} = 0.012), and mOFC – left subcallosal ACC connectivity were found (P_{FDR} = 0.036). A significant effect was found in NAcc – right posterior cingulate cortex (PCC) connectivity (P_{FDR} < 0.001) and NAcc – left cerebellum connectivity (P_{FDR} = 0.022). Lastly, ACC – bilateral vmPFC connectivity was found significant (P_{FDR} = 0.004). Regions of activation, including the MNI coordinate and cluster size, are outlined in Table 3.

Table 3. Effect of Basic Psychological Needs Satisfaction by life satisfaction group

Seed	Region	MNI coordinate, mm			Size	t	*p*
		x	y	z			
Group x Autonomy							
mOFC	R.Occipital	+10	-78	-22	1329	-6.62	*<0.001*
NAcc	B.FPC	-02	+62	-12	826	-5.58	*<0.001*
	B.mOFC	+20	+22	-18	537	4.72	*0.001*
Group x Competence							
Amygdala	B.mPFC	-06	+50	-04	410	4.71	*0.002*
Group x Relatedness							
mOFC	L.FPC	-08	+60	-06	406	-4.42	*0.002*
	R.Cerebellum	+28	-48	-38	276	-6.38	*0.012*
	L.sACC	-14	+38	-12	203	3.70	*0.036*
ACC	L.Cerebellum	-12	-62	-46	729	-7.44	*<0.001*
	B.vmPFC	-08	+38	-14	473	5.07	*0.004*
NAcc	B.PCC	+12	-42	+24	711	5.27	*<0.001*
	L.Cerebellum	-34	-80	-52	242	4.47	*0.022*

**Note.* Voxel threshold uncorrected P<0.005. Significant clusters at false discovery rate (FDR) P < 0.05. Abbreviation: MNI, Montreal Neurological Institute; t, peak T-score; mOFC, medial orbitofrontal cortex; NAcc, nucleus accumbens; mPFC, medial prefrontal cortex; FPC, frontopolar cortex; OFC, orbitofrontal cortex; sACC, subcallosal anterior cingulate cortex, vmPFC; ventromedial prefrontal cortex; PCC, posterior cingulate cortex; L, left; R, right; B, bilateral.

5. Post-hoc Analysis

Post-hoc analysis between major connectivities outlined above and the sub-scores of BPNS revealed the following. **Figure 1** shows the scatter plot of the relationship between the autonomy score and mOFC – right occipital cortex connectivity. In the LLS group, an increase in the autonomy level is associated with an increase in the connection mentioned above, while the opposite relationship is found in the HLS group. For this group, an increase in the autonomy level is associated with a decrease in mOFC – right occipital cortex connectivity.

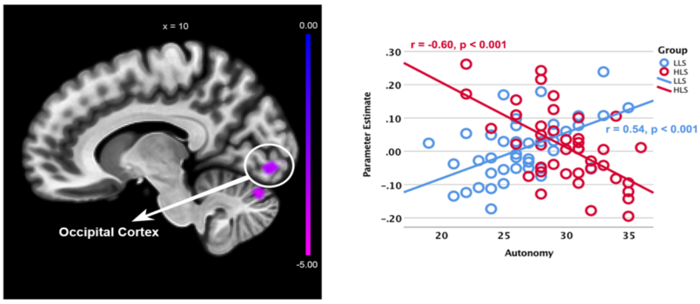

Figure 1. mOFC – right occipital cortex connectivity in relation to autonomy need satisfaction by life satisfaction group

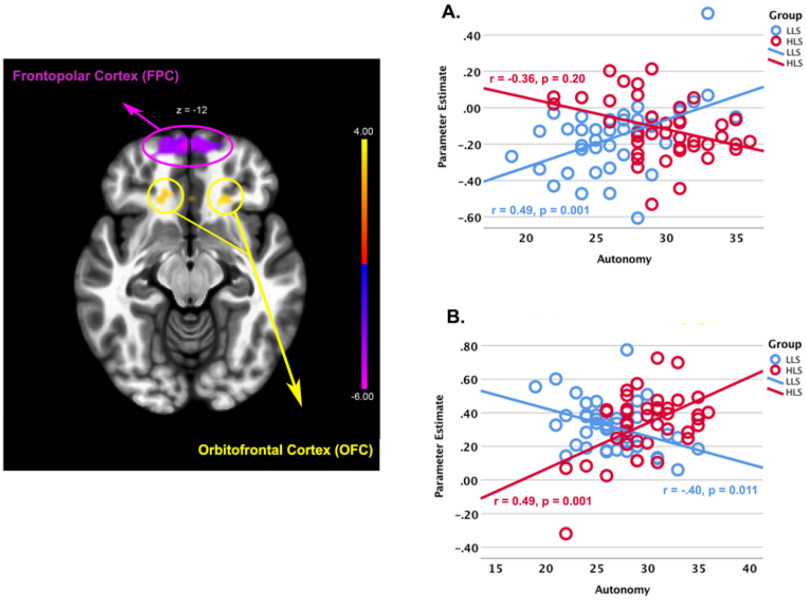

Figure 2. A) NAcc – bilateral FPC connectivity and B) NAcc – bilateral mOFC connectivity in relation to autonomy need satisfaction by life satisfaction group

A similar pattern was found with NAcc – bilateral FPC connectivity. An increase in the autonomy level was associated with an increase in connectivity strength for the LLS group and a decrease in connectivity strength for the HLS group (**Figure 2A**). However, an opposite pattern was found in the relationship between the autonomy score and NAcc – bilateral mOFC connectivity. In the LLS group, the increase in the autonomy score is associated with a decrease in connectivity strength and an increase in the strength of the HLS group (**Figure 2B**).

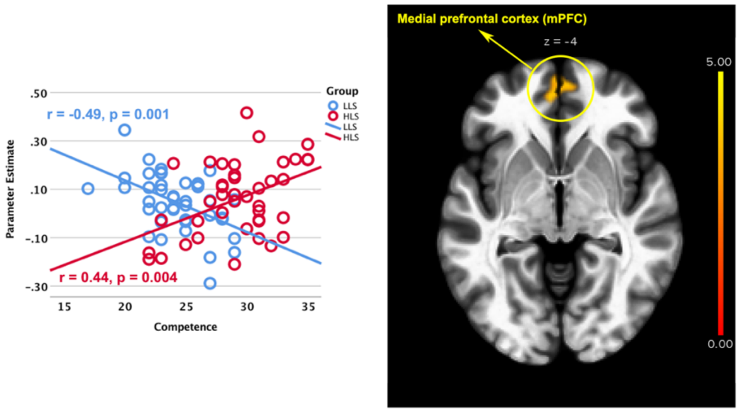

Figure 3. Amygdala – bilateral mPFC connectivity in relation to competence need satisfaction by life satisfaction group

Figure 3 shows the relationship between the competence score and amygdala – bilateral mPFC connectivity. In the LLS group, an increase in competence score is associated with a decrease in connectivity strength. In the HLS group, an increase in competence is associated with an increase in connectivity strength.

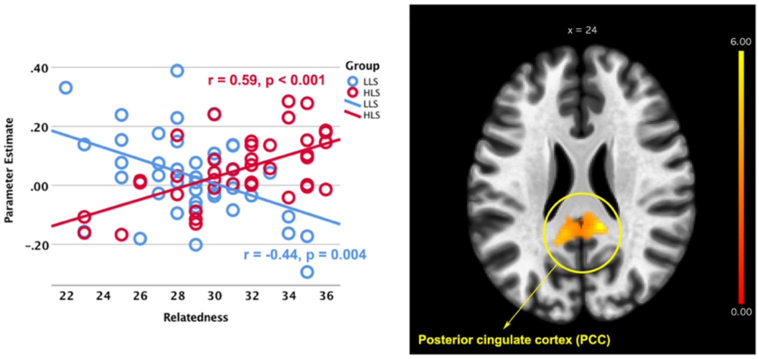

Figure 4. NAcc – bilateral PCC connectivity in relation to relatedness need satisfaction by group

Figure 4 shows the relationship between the relatedness score and NAcc – bilateral PCC connectivity. In the LLS group, the increase in the relatedness score is associated with a decrease in connectivity strength. Accordingly, in the HLS group, the increase in relatedness score is associated with an increase in connectivity strength.

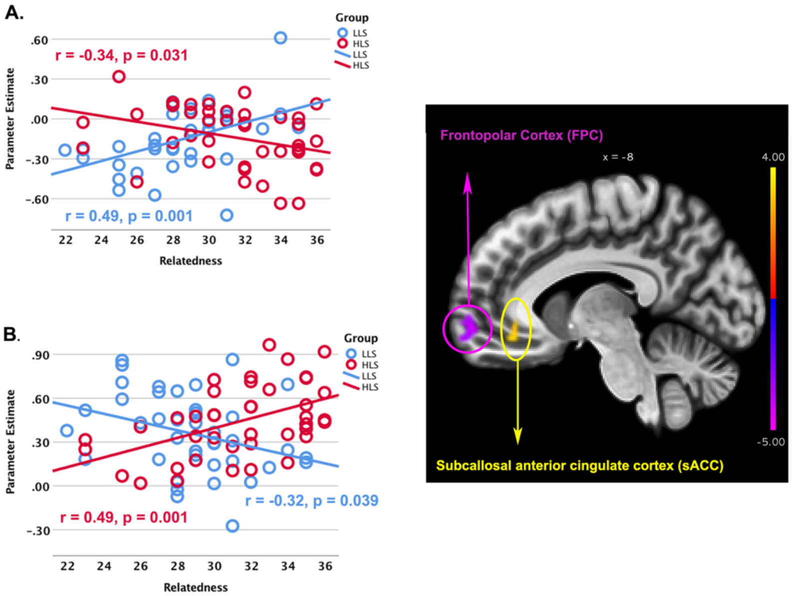

Figure 5. A) mOFC – left FPC connectivity and B) mOFC – left subcallosal ACC connectivity in relation to relatedness need satisfaction by life satisfaction group

Figure 5 shows the relationship between the relatedness score and mOFC seed connectivity. An increase in the relatedness score is associated with an increase in mOFC – left FPC connectivity for the LLS group and a decrease in connectivity for the HLS group (**Figure 5A**). An opposite relationship is found in mOFC – left subcallosal ACC connectivity (**Figure 5B**).

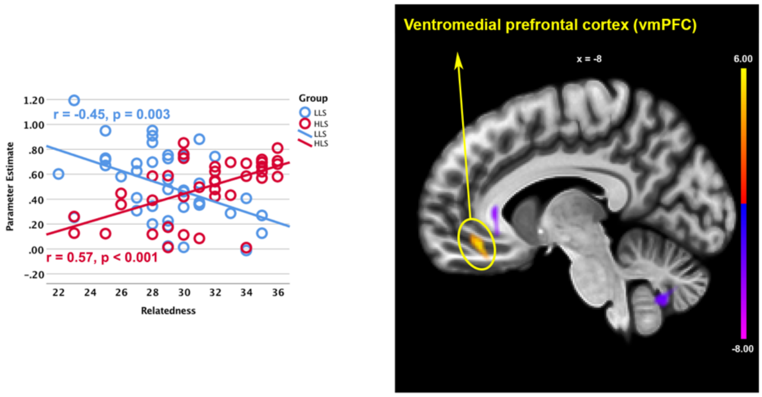

Figure 6. ACC – bilateral vmPFC connectivity in relation to relatedness need satisfaction by life satisfaction group.

Figure 6 shows the relationship between ACC seed connectivity and relatedness score. In the LLS group, an increase in the relatedness score is associated with a decrease in ACC–bilateral vmPFC connectivity, whereas in the HLS group, an increase in the relatedness score is associated with an increase in ACC-bilateral vmPFC connectivity.

IV. DISCUSSION

1. Life satisfaction and basic psychological needs satisfaction

Participants in both groups showed a significant difference in the reported sub-scores of BPNS. The two groups differed in the way each of the clinical and BPNS variables related to one another. For those with high life satisfaction, each of the BPNS scores correlated with one another, while for individuals with low life satisfaction, none of the scores were associated. It appears that those who are more satisfied with life are more well-rounded in each of the sub-components. In contrast, those who are relatively unsatisfied with life have an unbalanced needs satisfaction as each of the components appear to be unrelated. This is in line with previous findings that show that those with a more balanced needs satisfaction show greater levels of well-being.[35] From this, we can speculate that life satisfaction may be associated with maintaining balance in the three basic psychological needs satisfaction.

2. The neural basis of basic psychological needs satisfaction by group

Previous neuroimaging studies propose that intrinsic motivation, as regulated by the basic psychological needs support, is associated with the salience network and the reward system in the brain.[24] Since much of these findings are based on a task-based design, examining the brain at rest is critical in understanding innate differences in how each of the salience and reward networks functions. Moreover, this study attempted to investigate whether this difference may be influenced by life satisfaction. The presented findings suggest that individuals' perceived life satisfaction modulates the relationship between basic psychological needs support and reward processing in the brain. Individuals with high and low life satisfaction demonstrate an opposing trend in the association between each of the autonomy, competence, and relatedness score and functional connectivity of the regions involved in reward processing.

3. The neural basis of autonomy satisfaction by group

Autonomy satisfaction is one of the most critical, yet the most difficult to satisfy in modern society. Previous studies show that autonomy satisfaction sets the basis for competence and relatedness needs since these may not be satisfied unless individuals perceive one's behavior to be self-driven.[36,37]

The most noticeable finding is the significant difference in NAcc activity in individuals with high and low life satisfaction. The presented findings replicate previous literature that demonstrates the reward system in conceptualizing intrinsic motivation in the human brain.[24] According to this review, the VTA, NAcc, and vmPFC are highlighted as core structures that make up the reward system. Specifically, NAcc activity is associated with modulating motivation[38] and goal-oriented behavior.[39] Extending the results from previous literature that show activity of the mOFC, ACC, amygdala and NAcc on an experimental trial with monetary rewards,[40] the findings provide further evidence that life satisfaction plays a significant role in modulating the relationship between NAcc-based connectivity and autonomy fulfillment. In the same study, activation of frontal regions and the striatum correlated negatively with self-reported scores of intrinsic motivations, while the same areas showed a significant positive correlation with extrinsic motivation scores. Those with high intrinsic motivation showed diminished activity in response to monetary reward in the regions above.[40] Intrinsic motivation is found to be enhanced by free will and choice, which means that activities that foster intrinsic motivation will lead to autonomy fulfillment.[41,42] Provided that those with greater satisfaction of the autonomy needs have heightened intrinsic motivation, it can be inferred that only those with high life satisfaction show a similar decreasing trend in NAcc – bilateral FPC connectivity with increasing autonomy score.

The imbalanced activity of the NAcc and OFC is associated with disrupted inhibitory control.[43] Given the positive association between connectivity strength and autonomy score in individuals with high life satisfaction, the ability to control behavior becomes the basis of autonomy needs satisfaction. However, for individuals with low life satisfaction, the same intensity of connectivity is associated with lower levels of autonomy. It is unclear as to whether those with low life satisfaction have the specific overactive or underactive regions to explain for weakened connectivity with increasing autonomy level. For this reason, there is a need to conduct further analysis on uncovering the complex relationship between the motivational orientation of the individual, autonomy satisfaction, and reward centers in the brain.

4. The neural basis of competence satisfaction by group

There was a significant difference in amygdala activity specific to competence satisfaction in individuals with high and low life satisfaction. Extending the previous studies that show heightened amygdala, ACC, and insula activities when participants completed a free-choice activity,[44] the presented findings highlight the difference in amygdala connectivity associated with competence needs satisfaction. In particular, the functional coherence between the prefrontal and limbic region showed the most notable difference between the two groups. Given that the relationship between the amygdala and FPC plays a crucial role in the cognitive control of emotion,[45] for individuals with high life satisfaction, emotional control may be associated with competence satisfaction. Considering that such needs satisfaction equates with feeling self-worth and accomplishment, the sense of having self-control (i.e., the ability to inhibit unwanted emotions[46]) may ultimately satisfy individuals' competence needs. We provide evidence for this as the increase in competence score is associated with an increase in amygdala–bilateral mPFC connectivity in individuals with high life satisfaction. However, the opposite association was found for individuals with low life satisfaction. This may be indicative of an imbalance in amygdala–bilateral mPFC connectivity, where this effect is stronger for those with low life satisfaction with higher competence needs support. Further analysis must be conducted to examine this dissociation in relation to competence needs as modulated by the different levels of life satisfaction.

5. The neural basis of relatedness satisfaction by group

Based on the results, relatedness satisfaction demonstrates the most difference by group connectivity with the identified seed. The difference in the association of mOFC-based connectivity and relatedness score indicates that reward processing affects the need to interact with others in distinct ways based on life satisfaction. The mOFC is associated with internally and externally oriented self-relatedness,[47] the experience of regret,[48] reward processing and drug addiction.[49,50] In a more recent neuroimaging study, heightened activity of the vmPFC was associated with an autonomy-supporting, free choice experimental trial.[51] In the current study, significant mOFC connectivity was found in both autonomy and relatedness needs satisfaction. Moreover, such a relationship was found to be associated in distinct ways for the two groups. Provided that reduced amygdala–mOFC connectivity is related to social anxiety[52] and abnormalities in the mOFC is associated with depression,[53] it can be inferred from results in individuals with low life satisfaction that the relationship between lowered connectivity strength and relatedness needs satisfaction may be mediated by anxiety or depression. This assertion is strengthened by involvement of the left subcallosal ACC which is implicated in psychotic depression. Although additional analysis is necessary, the results provide demonstrate how life satisfaction can perhaps alter reward or decision values specific to forming and maintaining personal bonds with others.

The ACC and bilateral insula are mainly involved in conflict detection, self-control and error processing.[54-56] The results show that two groups employ different neural mechanisms in processing external events to guide goal-directed behavior. Considering that the interaction of the ACC and lateral prefrontal cortex plays a role in monitoring behavior,[55] the difference in group-by-autonomy interaction in ACC– bilateral vmPFC connectivity provides further evidence that life satisfaction may modulate this brain-behavior relationship. The two regions are implicated in integrating differential values in decision-making processes. The more efficient connection between the ACC and vmPFC allows individuals to shift towards choosing an option that leads to a long-term profit. In lines with this preliminary evidence, the presented findings for individuals with high life satisfaction also provide evidence of strong ACC—bilateral vmPFC connectivity in relation to relatedness need fulfillment.

Finally, the significant connection between the NAcc and bilateral PCC is noticeable. The PCC is involved in behavioral flexibility,[57] self-related and social processing.[58] As a key node in DMN, not only is this region is implicated in mentalizing and evaluating processes, but also in perspective-taking and reflecting on social events.[58] Based on this evidence, a stronger connection between the NAcc and bilateral PCC in individuals with high life satisfaction is associated with higher relatedness needs fulfillment. The opposite relationship in individuals with low life satisfaction may be due to the dysfunctional connection between the NAcc and bilateral PCC. Here, the results provide preliminary evidence in the recruitment of DMN in relation to relatedness needs satisfaction.

V. LIMITATION

There are some limitations to this study. First, self-reported questionnaires that measure the level of intrinsic or extrinsic motivation was not included in the study. This means that it is difficult to conclude that those with higher needs satisfaction for autonomy, competence, and relatedness are intrinsically motivated. These behavioral tendencies may differ depending on different contexts, such as at work or during a leisure activity. Also, the sample of participants is limited to a single culture (i.e., university students from Korea). Future studies should look at the influence of cultural factors that may play a role in supporting or thwarting basic psychological needs.[36] Cross-cultural exploration of the neural underpinnings of each of the basic psychological needs is necessary to examine the influence of social or cultural factors.

VI. CONCLUSION

Previous neuroimaging studies propose that intrinsic motivation, as regulated by the basic psychological needs support, is associated with the salience network and the reward system in the brain. Since the previous results are based on a task-based experimental set-up, there is a need to examine the differences in resting connectivity of the brain in relation to the three constructs of the basic psychological needs. The current findings provide critical information that suggests individuals' perceived life satisfaction affects the relationship between the basic psychological needs support and salience and reward processing in the brain. Therefore, the proposed research gives insight into the relationship between the different levels of autonomy, competence, and relatedness support and changes in the strength of resting-state connectivity as modulated by life satisfaction.

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ABSTRACT(IN KOREAN)

자기결정성이론에 근거한 기본 심리 욕구 만족도의
신경학적 기전

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자기결정성이론의 주요 요소인 자율성, 유능감, 그리고 관계성에 대한 신경학적 기전을 알아보는 것이 목적이다. 개인의 심리적 행복을 유지하기 위해서는 이 세가지 요소가 충족되어야 한다. 본 연구에서는 삶의 만족도가 높고 낮은 집단의 뇌 기능적 연결성 차이를 조사함으로써 기본적인 심리적 욕구 충족과 동기 부여에 대한 기전을 밝힌다.

청년층 83명(평균연령 22.9, SD = 2.46)을 높은 만족도와 낮은 삶의 만족도 그룹으로 나눠 삶의 만족도, 기본 심리적 욕구 만족도, 자존감, 불안과 우울감을 측정했다.

5분 휴식 상태의 fMRI 이미지를 분석한 결과 내측 안와전두피질(medial orbitofrontal cortex)와 후두 피질(occipital cortex)에서의 상호작용 효과가 나타났고 측좌핵(nucleus accumbens)와 전두극피질(frontopolar cortex) 그리고 측좌핵과 안와전두피질 간의 효과가 유의했다.

유능감 점수에 관해서는 편도체(amygdala)와 내측전전두엽(medial prefrontal cortex)간의 효과가 유의했다. 마지막으로 관계성 만족도는 측좌핵과 후대상피질(posterior cingulate cortex)간의 효과가 유의했다. 이러한 발견은 개인의 삶의 만족도가 심리적 욕구 지지 정도와 보상 처리 사이의 관계에 영향을 미친다는 것을 시사한다.

핵심되는 말 : 자율성, 유능감, 관계성, 내재 동기, 보상 과정, 휴지상태 뇌기능 연결성