Physiological correlates of happiness: Role of serotonin and BDNF

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Abstract

Serotonin (5-HT) and brain-derived neurotrophic factor (BDNF) are two molecules strongly associated with negative affect, however, research is limited regarding their association with positive affect. To investigate the relation between 5-HT, BDNF, and positive affect, this study compared concentrations of 5-HT (n = 23) and BDNF (n = 36), as determined by enzyme immunoassays of morning urine samples, with psychological measures of positive and negative affect. To assess positive affect, overall and momentary happiness were rated twice over three days using the Faces Scale. As expected, overall happiness ratings across time were strongly correlated ($r = .88$, $p < .05$), whereas, momentary happiness ratings did not correlate ($r = .01$, $p = .93$), indicating that the Faces Scale is a valid measure of happiness. While statistically significant correlations between 5-HT and psychological variables were mostly not observed, trends between 5-HT and affective measures are encouraging. BDNF did not appear to be accurately measured in this sample, therefore conclusions could not be made between BDNF and positive affect.

Physiological correlates of positive affect: Role of serotonin and BDNF

Serotonin (5-hydroxytryptamine; 5-HT) is a monoamine neurotransmitter involved in regulation of a range of behaviours including sleep, appetite, arousal, and aggression (Carlson, 2007). 5-HT activity is correlated with variations in personality and mood, and is also linked to the etiology of depression (Depue, 1995). According to the widely-accepted monoamine hypothesis of depression, dysfunction of monoaminergic systems may underlie the symptoms of depression (Depue, 1995; Sheline et al., 1995; Spoont, 1992). This hypothesis is supported by evidence from drug therapies. For example, selective serotonin reuptake inhibitors (SSRIs) are a class of antidepressant drugs that alleviate symptoms of depression by increasing the functional level of 5-HT at synapses. However, clinical improvements often only occur after several weeks of drug therapy, despite levels of 5-HT often improving after several days of initial drug administration. The apparent delay between neurochemical changes and clinical improvements suggests that the monoamine hypothesis is not a sufficient explanation of the neurobiology of depression. Recent research has been investigating other cellular mechanisms that that may contribute to the biological basis of mood disorders.

In addition to neurochemical changes occurring in individuals with depression, structural alterations and neuronal plasticity impairments have been observed (Duman & Monteggia, 2006; Duman, Malberg, Nakagawa, & D'Sa, 2000). Recent evidence has demonstrated that depression is associated with increased cell atrophy and decreased volumes of various brain structures, most notably the hippocampus (Sheline, 2003) and prefrontal cortex (Rajkowka et al., 2000). This evidence has lead to the development of the neurotrophic model of depression. This model suggests that decreased levels of neurotrophins may be a contributing factor to the physiological basis of depression. Neurotrophins are an important family of proteins required throughout the

lifespan to facilitate neuronal development, function, plasticity, and survival (Castrén, Võikar, & Rantamäki, 2006). Inadequate levels of neurotrophins are associated with plasticity impairments and increased probability of apoptosis (i.e., programmed cell death) (Duman et al., 2000). Decreased levels of a specific neurotrophin, brain-derived neurotrophic factor (BDNF), have recently been linked to the etiology of depression. It is surmised that low levels of BDNF causes a reduced expression of certain nuclear genes, resulting in a decreased production of proteins that promote cellular resistance and neuronal plasticity (Manji, Drevets, & Charney, 2001). Plasticity refers to a neuron's ability to alter synaptic connections in response to experience, and is necessary for the acquisition and storage of new information and memories (Duman, 2002). BDNF does not directly influence mood, rather, it is hypothesized to be involved in the regulation of cellular networks that are responsible for mood and cognition.

The neurotrophic model of depression has been strongly supported by several lines of evidence: 1) untreated depressed patients demonstrate decreased levels of BDNF as compared with non-depressed controls (Karege et al., 2002); 2) depressed patients receiving successful antidepressant therapy show increased levels of BDNF (Gonul et al., 2005; Duman, & Monteggia, 2006); 3) a negative correlation between blood serum concentration of BDNF and the personality trait *neuroticism*, a known predictor of depression, has also been observed (Lang, Hellweg, and Gallinat, 2004); and 4) increased levels of stress, which often precedes and exacerbates the symptoms of depression, decreases the expression of BDNF (Smith, Makino, Kvetnansky, & Post, 1995). Animal studies corroborate evidence from human studies. For example, infusion of BDNF into the midbrain of rats produces antidepressant-like effects (Shirayama et al., 2002).

The neurotrophic model is not intended to replace the monoamine hypothesis, but rather develop it. BDNF has been demonstrated to promote proliferation and plasticity of serotonergic neurons, linking BDNF activity to variability of 5-HT activity (Mamounas, Blue, Sluciak, & Altar, 2000; Mössner et al., 2000). Moreover, increases of 5-HT concentration and the administration of 5-HT receptor agonists increase the expression of BDNF mRNA (Vaidya, Marek, Aghajanian, & Duman, 1997; Zetterstrom, Pei, Madav, Lewis, & Grahame-Smith, 1999). Together, the monoamine and neurotrophic hypotheses lead to a more sophisticated understanding of the biological basis of depression.

The increasing prevalence and debilitating effects of depressive symptoms, has motivated intense research investigating the biological basis of mood disorders and negative affect. However, the immense volume of research investigating pathophysiology has yet to be paralleled by research of positive affect. Positive psychology is a relatively new field of psychology addressing this disparity by encouraging research that develops understanding of positive affect (Seligman & Csikszentmahayli, 2000). Specifically, this emerging field is focused on identifying contributing factors and various effects of positive subjective experiences and emotions, such as hope, optimism, and spirituality. Positive affect is a term encompassing various components, including happiness, contentment, life satisfaction, optimism, and well-being (Seligman et al., 2000). Positive psychology encourages a proactive prevention of psychological illness by identifying attitudes and personality traits that contribute to positive mood and increase quality of life, thereby providing a buffer against depression (Seligman et al., 2000).

Research has identified many benefits associated with positive affect. For example, happy people, as compared with less happy people, tend to have greater immune system functioning, a reduced risk of cardiovascular disease, and report greater marriage and job

satisfaction (Lyubomirsky, King, & Diener, 2005; Steptoe, Wardle, & Marmot, 2005). It is therefore valuable to develop a deeper understanding of the positive affect by investigating its biological basis. Several studies have begun to investigate potential biological markers of positive affect.

Research investigating the association between one potential biological marker, 5-HT, and positive affect have produced mixed results. Zald and Depue (2001) assessed the correlation between 5-HT activity and both positive and negative affect in a sample of males. Affect was assessed using the Positive and Negative Affect Schedule (PANAS), and serotonergic activity was determined by administration of a fenfluramine challenge. The fenfluramine challenge is an indirect measure of central 5-HT activity, as administration of fenfluramine induces increased release of prolactin into the blood, via activation of hypothalamic 5-HT receptors. This procedure involves oral ingestion of fenfluramine, followed by many blood samples obtained from participants throughout the day to assess the resulting prolactin concentration. Depressed individuals provide a decreased, or blunted, response to fenfluramine administration (i.e., have a lower concentration of prolactin) as compared with controls. Zald et al. obtained a *negative* correlation between prolactin response and both positive and negative affect. That is, as prolactin response increased (i.e., 5-HT levels increased), levels of positive and negative affect decreased. The authors suggested that increased levels of 5-HT may constrain general affective processes. However, this conclusion appears inconsistent with some clinical literature. For example, SSRI administration appears to increase positive mood in non-depressed individuals, suggesting a positive correlation with positive affect (Barge-Schaapveld et al., 1995). If 5-HT were to constrain affect, then 5-HT would be expected to be *negatively* correlated with level of positive affect.

Flory, Manuck, Matthews, and Muldoon (2004) investigated positive affect and 5-HT activity using the same indices (i.e., PANAS and the fenfluramine administration) as did Zald et al. (2001). However, Flory et al. improved upon methodology by obtaining a larger sample size, and including both male and females. Unlike Zald et al., Flory et al. demonstrated a *positive* correlation between prolactin response and positive affect; however, a significant correlation between prolactin response and negative affect was not obtained, suggesting the 5-HT levels are not associated with negative affect. The authors conclude that these results are consistent with the notion that low levels of 5-HT are associated with low levels of positive affect.

Studies investigating the biochemical basis of affect using whole-blood samples to assess 5-HT functioning have been recently conducted (Duffy et al., 2006; Williams et al., 2006). Whole-blood indices of serotonergic activity indicate that 5-HT levels are positively associated with positive affect, but are unrelated to negative affect (Duffy et al., 2006; Williams et al., 2006). It remains puzzling as to why whole-blood 5-HT levels are not related to negative affect in these studies. These results are from one study that used a small sample consisting of men only (Duffy et al., 2006), and another study that used a sample of postmenopausal women only (Williams et al., 2006). Therefore, replication of this study using a large sample of both sexes would be valuable.

The present study examined the relation between positive affect and 5-HT and BDNF. Despite its strong link to negative affect, it appears that no study has investigated the association between BDNF and positive affect. Two hypotheses were examined: 1) both 5-HT and BDNF are negatively correlated with measures of negative affect; and 2) both 5-HT and BDNF are positively correlated with measures of positive affect.

Additionally, this study examined the validity of the Faces Scale (see Methods for description) as a measure of "overall" and "momentary" happiness. Happiness, a component of positive affect, cannot accurately be assessed without considering both stable, internal factors (i.e., personality traits), and unstable, external factors (i.e., environmental circumstances) (Chaplin, John, & Goldberg, 1988). Therefore, it is important to recognize and measure two distinct components in the assessment of happiness: 1) happiness as a personality *trait* (i.e., a stable, internal characteristic); and 2) happiness as an emotional *state* (i.e., a temporary, fluctuating characteristic responding to external events) (Csikszentmihalyi & Hunter, 2003). The current study assessed both these components of happiness by asking participants to rate their overall (i.e., trait) and momentary (i.e., temporary) happiness level on the Faces Scale (see Appendix B). If the Faces Scale is a valid measure of trait happiness, it is predicted that multiple self-ratings of overall happiness would be consistent over time. If the Faces Scale is a valid measure of state happiness, then multiple self-ratings of momentary happiness are predicted to *not* be consistent across time.

Method

Participants

Sixty participants (48 females, 12 males) from the University of British Columbia completed the study after providing informed consent (See Appendix A). The mean age of the participants was 20 years, ranging from 18 to 27 years. Participants were excluded if they had taken antidepressant medication within the 6 months preceding the study. Participants received course credit for their participation.

Materials

Affective Assessment

Four questionnaires were administered to assess affect: Faces Scale, Oxford Happiness Questionnaire, Satisfaction with Life Scale, and the Centre for Epidemiological Studies – Depression Scale.

Faces Scale. The Faces Scale assesses happiness by using illustrations of simple faces. Seven cartoon-like faces, depicting affect ranging from very unhappy to very happy, are presented in a row, following a question or an item pertaining to happiness. The face that best represents one's level of happiness is selected by the participant. In this study, participants responded to two items using this scale to determine "overall" happiness and "momentary" happiness (see Appendix B). The overall happiness item intends to assess happiness as a stable personality trait; conversely, the momentary happiness item intends to assess happiness as a fluctuating emotional state (Csikszentmihalyi & Hunter, 2003). The Faces Scale demonstrated good validity in previous research of positive affect (Holder & Coleman, in press).

Oxford Happiness Questionnaire. The Oxford Happiness Questionnaire (OHQ) assesses positive affect (Hills & Argyle, 2002) (see Appendix D). The OHQ is a short-form version of the Oxford Happiness Inventory (OHI). The OHI was developed for experimental, not diagnostic, purposes, and has been demonstrated to be valid cross-culturally (Hills et al., 2002). The OHQ is composed of 29 items, and its format is similar to the Beck Depression Inventory. Example items are as follows: "I often experience joy and elation" or "I am not particularly optimistic about the future" (reverse scored item). Six response categories range from 1 "strongly disagree" to 6 "strongly agree". The OHI and OHQ strongly correlate with each other indicating measurement of the same construct (Hills et al., 2002). Internal and construct validity have been established for the OHQ (Hills et al., 2002).

Satisfaction with Life Scale. Life satisfaction is considered a component of subjective well-being (Diener, Emmons, Larsen, & Griffin, 1985). The Satisfaction with Life Scale (SWLS) is a widely-used brief 5-item measure of global life satisfaction (Diener et al., 1985). An example item is "I am satisfied with my life". Response categories for each item ranges from 1 "strongly disagree" to 7 "strongly agree". This scale has demonstrated high internal consistency and high temporal reliability (Diener et al., 1985).

Centre for Epidemiological Studies – Depression Scale. Negative affect was assessed using the Centre for Epidemiological Studies – Depression Scale (CES-D) (Radloff, 1977). The CES-D is a 20-item scale developed for experimental measurement of depressive symptomology in the general population. It is not intended for diagnostic purposes. Items are statements for which participants indicate the frequency with which they had agreed with the statement in the past week. Example statements include "I felt depressed" and "I thought my life had been a failure". Four response categories ranged from "Rarely or None of the Time (Less than 1 Day)" to "Most or All of the Time (5-7 Days). This scale has demonstrated adequate test-retest reliability, high internal consistency, and strong construct validity (Radloff, 1977).

Biological Assessment

This study obtained urine samples to index 5-HT and BDNF functioning. Unlike the collection of blood samples or the administration of the fenfluramine challenge, urine sample collection is low-risk and non-invasive. To ensure procedural homogeneity, all urine samples were collected immediately upon awakening. Participants were instructed to provide a midstream sample (approximately 150 ml) of their first morning emission. Both 5-HT and BDNF are located in the central and peripheral nervous systems; therefore, results from this study should be

interpreted with caution as current literature is lacking regarding the validity of urinary 5-HT and BDNF concentrations as indicators of central nervous system activity.

Enzyme immunoassays (EIAs) were performed in duplicate using commercial ELISA kits within 6 weeks of sample collection. 5-HT analysis (*n = 31)* was performed according to manufacturer's instructions (Alpco Diagnostics, Salem, USA). The lower limit of sensitivity of this assay is 5 ng/ml. BDNF analysis (*n = 36)* was performed according to manufacturer's instructions (RayBiotech, Inc., Norcross, USA). The lower limit of sensitivity of this assay is 3 pg/ml. Absorbencies for both assays were measured at 450 nm, using an Opsys MR™ 96-well microplate reader (Dynex Yechnologies) using Windows® Revelation QuickLink™ software.

Procedure

Participant testing began following ethical approval from the Research Ethics Board of the University of British Columbia. Each participant was tested over three days. On Day one, participants provided informed consent, were given verbal instructions of the procedure, and were provided with sterile containers to take home. At this time, participants also rated their overall and momentary happiness using the Faces Scale. On Day two, participants abstained from consumption of foods known to affect urinary analysis of 5-HT: bananas, pineapple, walnuts, pecans, tomatoes, plums, and kiwi (Feldman & Lee, 1985; Kema, Schellings, Meiborg, Hooerbrouwers, & Muskiet, 1992). On Day three, urine samples were collected immediately after awakening at the participants' home. Samples were brought to laboratory within several hours and stored at -20 ˚C. Participants completed the psychological measures, including a re-administration of the Faces Scale, and a demographic form (see Appendix C). Faces Scale happiness ratings given on Day one are referred to as Overall T1 and Momentary T1; ratings given on Day three are referred to as Overall T2 and Momentary T2.

Results

The data were analyzed using SPSS version 12.0. Pearson correlation coefficients were calculated to evaluate relations between variables. An alpha level of .05 was adopted for all statistical tests.

Affective Analysis

Data from all 60 participants were included in the psychometric analysis. A frequency distribution of responses on the Faces Scale (see Figure 1) indicates that the majority of ratings (approximately 85 to 90%) of both the overall and momentary were in the top three categories. Correlations between psychological measures are presented in Table 1. Overall T1 and Overall T2 happiness ratings were highly positively correlated (r = .88, $p < .05$); whereas ratings of Momentary happiness at T1 and T2 were not correlated (r = .01, $p = .93$). Scores from the OHQ were highly positively correlated with Overall T1 (r = .71, $p < .05$) and Overall T2 happiness (r = .67, $p < .05$) ratings, and were moderately positively correlated with momentary T1 (r = .34, $p < .05$) and momentary T2 (r = .33, $p < .05$) happiness ratings. The SWLS was positively correlated with Overall T1 (r = .52, $p < .01$), Overall T2 (r = .55, $p < .01$), and Momentary T1 happiness (r = .28, $p < .05$), but not Momentary T2 (r = .10, $p = .46$). A positive correlation was also observed between the SWLS and the OHQ (r = .66, $p < .01$). The CES-DS was weakly to moderately negatively correlated with Overall T1 (r = -.56, $p < .01$), Overall T2 (r = -.58, $p < .01$), Momentary T1 (r = -.33, $p < .01$), and Momentary T2 (r = -.30, $p < .01$). The CES-DS was moderately negatively correlated with the OHQ (r = -.70, $p < .01$) and the SWLS (r = -.61, $p < .01$).

5-HT Analysis

EIAs were performed to determine 5-HT concentrations (ng/ml) of the urine samples (*M* = 786, *SD* = 687). Although 60 samples were collected, only 31 were analyzed due to kit supply limitations. Six participants did not complete the dietary restriction as instructed (*M* = 1157, *SD* = 1226) and were excluded from subsequent statistical analyses. An additional participant, who correctly followed protocol, was also excluded as her 5-HT concentration was 3.2 SD above the mean and was considered an outlier. Therefore, concentrations from only 23 participants (*M* = 786, *SD* = 687) were used to evaluate the relation between urinary 5-HT concentration and affect. 5-HT concentrations ranged from 16 to 1678 ng/ml. Correlations coefficients between urinary 5-HT concentrations and psychological measures are presented in Table 2. A significant positive correlation was observed between 5-HT and overall T2 happiness (r = .46, $p < .05$); no other scale was significantly correlated with 5-HT concentration. A plot of CES-DS scores against 5-HT concentration suggests a negative trendline as predicted (see Figure 2). Similarly, plots of average T1 and T2 overall happiness, T1 and T2 momentary happiness, and the OHQ illustrate trendlines in the predicted positive direction (see Figures 3 to 5).

BDNF Analysis

EIAs were performed to determine BDNF concentrations (pg/ml) for 36 urine samples (*M* =5.11, *SD* = 2.18). As previously mentioned, not all 60 samples could be analyzed due to kit supply limitations. BDNF concentrations ranged from 3 to 12 ng/ml. Table 2 presents correlations between BDNF concentration and scores from the six psychological measures, none of which were significant. A plot of scores on the CES-DS against BDNF concentration confirms an absence of a linear relation between depression and BDNF, as demonstrated by a nearly horizontal trendline (see Figure 6). Similarly, a horizontal trendline is apparent in a plot of average overall T1 and T2 happiness scores against BDNF concentration (see Figure 7).

Discussion

This study is the first, to our knowledge, to assess the relation between positive affect and urinary concentrations of 5-HT and BDNF. A positive correlation between 5-HT and Overall T2 happiness suggests a relation between these variables. However, 5-HT was unexpectedly not significantly associated with the other measures of affect, suggesting no relation between urinary 5-HT and affect. BDNF was not found to be significantly associated with any of the affective measures, suggesting no relation between urinary BDNF and affect.

Prior to conclusions being drawn about the relation between positive affect and 5-HT and BDNF, it is necessary to evaluate the validity of our measures. Foremost, was affect successfully measured? The majority of ratings of overall and momentary happiness on the Faces Scale occurred the top three categories (see Figure 1), indicating that most participants were happy at the time of testing. This result is consistent with findings from the general population, suggesting that happiness was validity measured (Myers, 2000). Overall happiness is mediated by stable personality traits, thus multiple assessments are consistent over time (Csikszentmihalyi et al., 2003). State happiness fluctuates with the time of day, day of the week, and activity type (e.g., leisure versus work), thus multiple assessments are variable and inconsistent over time (Csikszentmihalyi et al., 2003). The present study therefore hypothesized that Overall T1 happiness would be strongly correlated with Overall T2 happiness, and that Momentary T1 happiness would not be correlated with Momentary T2. As shown in Table 1, results support this hypothesis, suggesting that overall and momentary happiness were validly measured using the Faces Scale. Correlations between the Faces Scale and the OHQ also suggest that overall and momentary happiness were validly assessed. The OHQ is intended to be a broad stable measure of happiness, therefore it was expected that overall happiness would be more strongly correlated

with the OHQ than would momentary happiness. Supporting this hypothesis, results demonstrated that Overall T1 and T2 happiness ratings were more strongly correlated with the OHQ than were momentary T1 and T2 happiness ratings.

The SWLS was strongly positively correlated with overall happiness and the OHQ. The SWLS was only weakly positively correlated with momentary T1 happiness, and was *not* correlated with momentary T2 happiness. While the SWLS is not intended to directly assess positive affect, both life satisfaction and positive affect are a component of subjective well-being, and therefore are expected to be related (Diener, Emmons, Larsen, & Griffin, 1985). Assessment of both life satisfaction and overall happiness requires a broad, cognitive appraisal of one's life, whereas assessment of momentary happiness is assumed to be a less cognitively-demanding judgment of current emotionality. Therefore, it is as expected that the SWLS is positively correlated with overall happiness, but not (or only weakly) correlated with momentary happiness. Results from the SWLS further increases confidence that positive affect was validity assessed.

If affect were validly assessed, it would also be expected that measures of positive affect would be negatively correlated with levels of depression, since depression is associated with decreased levels of positive affect (Forbes & Dahl, 2005). As expected, negative correlations were observed between the CES-DS and all six measures of positive affect, with the OHQ having the strongest correlation, and momentary T1 and T2 happiness ratings having the weakest correlation. The OHQ was expected to have the strongest correlation with the CES-DS since it is a more sophisticated measure of happiness than the Faces Scale. Momentary happiness ratings expectedly had the weakest correlation with the depression levels since momentary happiness is

susceptible to unstable environmental factors that may decrease positive affect. In short, it can be concluded that both positive and negative affect were validly assessed in this study.

Was 5-HT validly measured in this study? While a lack of significant predicted correlations (with the exception of overall T2 happiness) between 5-HT and affective measures (see Table 1) suggests that 5-HT may not have been validly measured, there is reason to assume that the assessment of 5-HT was valid. Figure 2 demonstrates a negative trend between negative affect and 5-HT, and Figures 3 to 5 demonstrates a positive trend between positive affect and 5-HT. These trends occurred in consistent and predicted directions, suggesting that a relation may be present between these variables. Why then was only one correlation significant? A relatively small sample (23 participants) was used to assess the relation between urinary 5-HT and affect, resulting in low statistical power. Therefore, it is probable that low statistical power accounts for the lack of significant correlations, rather than an invalid measure of 5-HT or an absence of a relation between affect and urinary 5-HT. Other studies assessing the association between biological markers and positive affect in both males and females collected data from 118 or more participants. Future work for the present study should obtain a similar sample size.

If future research obtains greater statistical power and does find a significant positive correlation between urinary 5-HT and positive affect, then these results would be supportive of previous research that found a positive relation using the fenfluramine challenge (Flory et al., 2004) and whole-blood samples to index 5-HT activity (Duffy et al., 2006; Williams et al., 2006). If urinary 5-HT is associated with positive affect, this would allow future research to use urine samples to assess 5-HT activity, instead of invasive procedures such as the fenfluramine challenge and obtaining blood samples. Since urinary sampling is a convenient, low-risk procedure, obtaining participants for studies may become easier, allowing for larger samples to

be collected. This would improve current methodology by increasing statistical power and confidence in results.

Was BDNF validly measured in this study? Results suggest that BDNF was not accurately measured for several reasons. Foremost, BDNF concentrations obtained in this study were not similar to concentrations found in the general population. Previous research that determined BDNF concentration in blood samples found a mean concentration of approximately 16 ng/ml, which is several orders of magnitude higher than the present study's mean of approximately 5 pg/ml. Secondly, the lower limit of sensitivity to measure BDNF using EIA is 3 pg/ml; most of the samples were near this value suggesting that floor effects may have occurred. That is, there may not be enough variability to accurately assess concentrations between participants. Thirdly, previous research suggested that BDNF would negatively correlate with levels of depression; however, this was not observed (see Figure 6), confirming that BDNF was not validity assessed. Given that BDNF assessment does not appear valid, conclusions cannot be drawn from these data about the nature of the relation between BDNF and positive affect. It would be worthwhile for future research to attempt to measure urinary BDNF, as methodological error may account for these data in this instance. If future work is unable to validity measure BDNF in urine, research may need to continue obtaining blood samples to assess the relation between BDNF and affect.

Future research investigating potential biological markers of positive affect may seek markers other than 5-HT and BDNF. For example, it is hypothesized that stress is associated with the negative affect and the onset of depression (Duman et al., 2006). If this is true, then perhaps markers of stress could be compared with positive affect. Stress is known to negatively impact immune system functioning, therefore, future research could to assess markers of immune

functioning (e.g., the concentration of immunoglobulins in blood) to determine the relation between stress and positive affect. There are multiple benefits to identifying a reliable and valid biological marker of positive affect. Primarily, identification and characterization of biological markers would provide insight about the physiological basis of positive emotionality. Secondly, biological markers of positive affect could be used to investigate the relation between positive affect and negative affect, perhaps leading to a better understanding of depression. Lastly, researchers could compare measures of positive affect with the biological marker, providing an objective method of assessing the validity of affective measures though convergent validity.

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Table 1

Pearson correlations between psychological scales (N = 60)

Scale	1	2	3	4	5	6	7
1. Overall T1	-	.88**	.32*	.19	.71**	-.56**	.52**
2. Overall T2		-	.23	.17	.67**	-.58**	.55**
3. Momentary T1			-	.01	.34**	-.33**	.28*
4. Momentary T2				-	.33**	-.30*	.10
5. OHQ					-	-.70**	.66**
6. CES-DS						-	-.61**
7. SWLS							-

* indicates a significant correlation at the .05 level (2-tailed)

** indicates a significant correlation at the .01 level (2-tailed)

Table 2

Pearson correlations between 5-HT (n = 23) and BDNF (n = 36) concentrations and psychological measures

Scale	5-HT	BDNF
Overall T1	.34	.04
Overall T2	.46*	-.11
Momentary T1	.33	-.07
Momentary T2	.22	-.12
OHQ	.28	-.14
CES-DS	-.34	-.10
SWLS	.10	-.10

* indicates a significant correlation at the .05 level (2-tailed)

Figure 1

Proportion of ratings of overall and momentary happiness at T1 and T2 (N = 60)

Overall T1	0%	0%	5%	7%	43%	38%	7%
Overall T2	0%	0%	3%	7%	32%	50%	8%
Momentary T1	0%	1.7%	1.7%	10%	27%	48%	12%
Momentary T2	0%	0%	5%	10%	37%	35%	13%

Figure 2

Centre for Epidemiological Studies – Depression Scale score plotted against concentration of urinary 5-HT (ng/ml) (r = -.34; p = .11; n = 23)

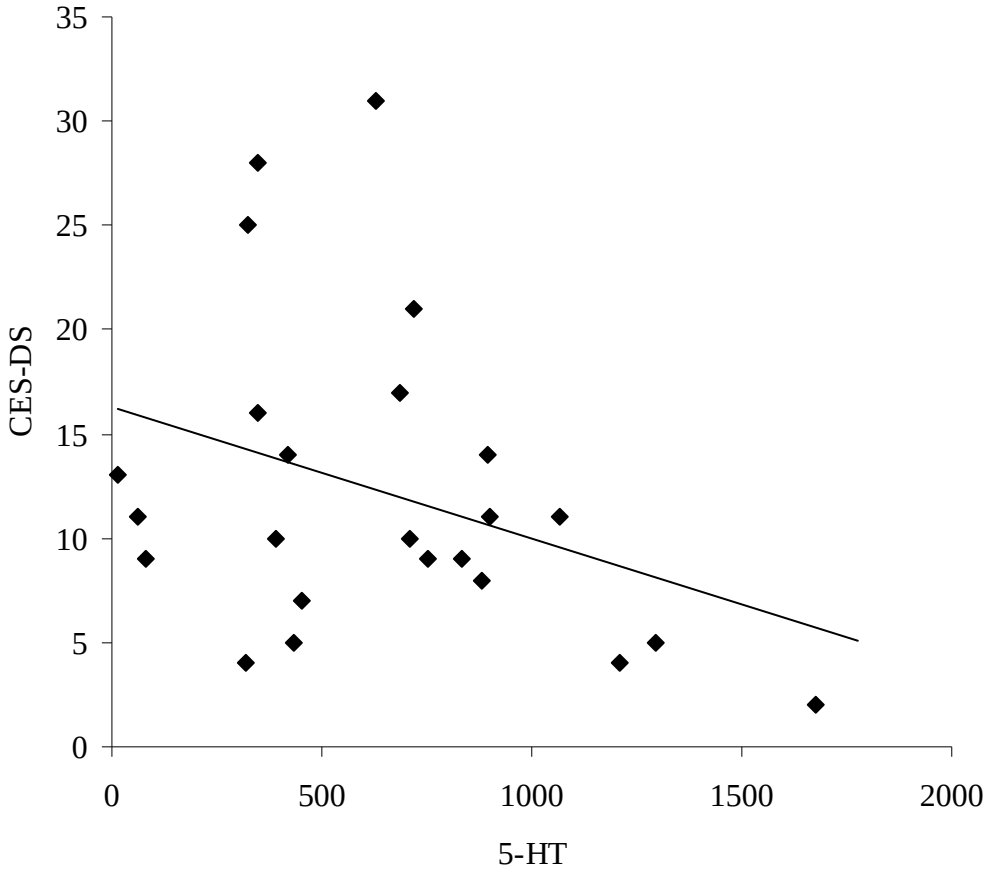


Figure 3

Mean overall T1 and T2 happiness rating plotted against concentration of urinary 5-HT (r = .41; p = .053; n = 23)

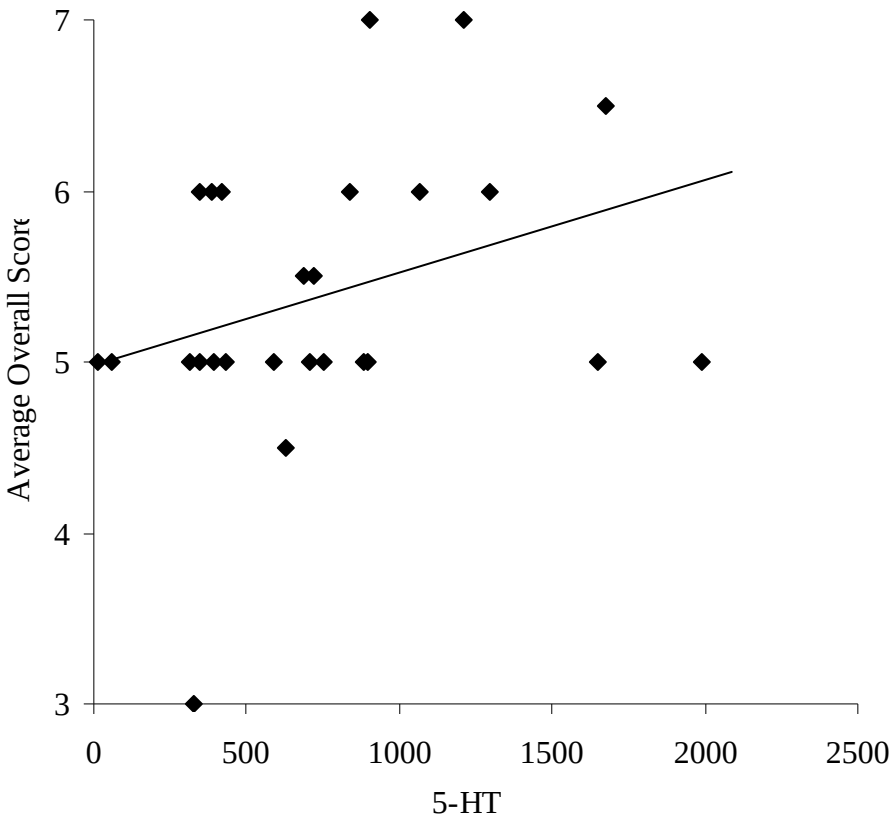
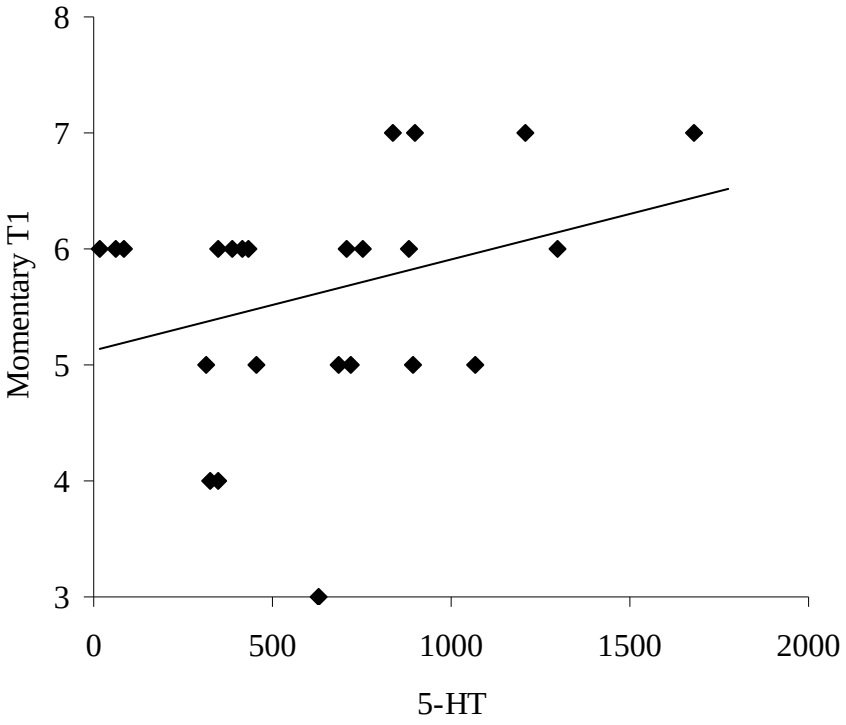


Figure 4

Momentary T1 (r = .33; p = .12) and momentary T2 (r = .22; p = .32) happiness ratings plotted against urinary concentrations of 5-HT (ng/ml) (n = 23)



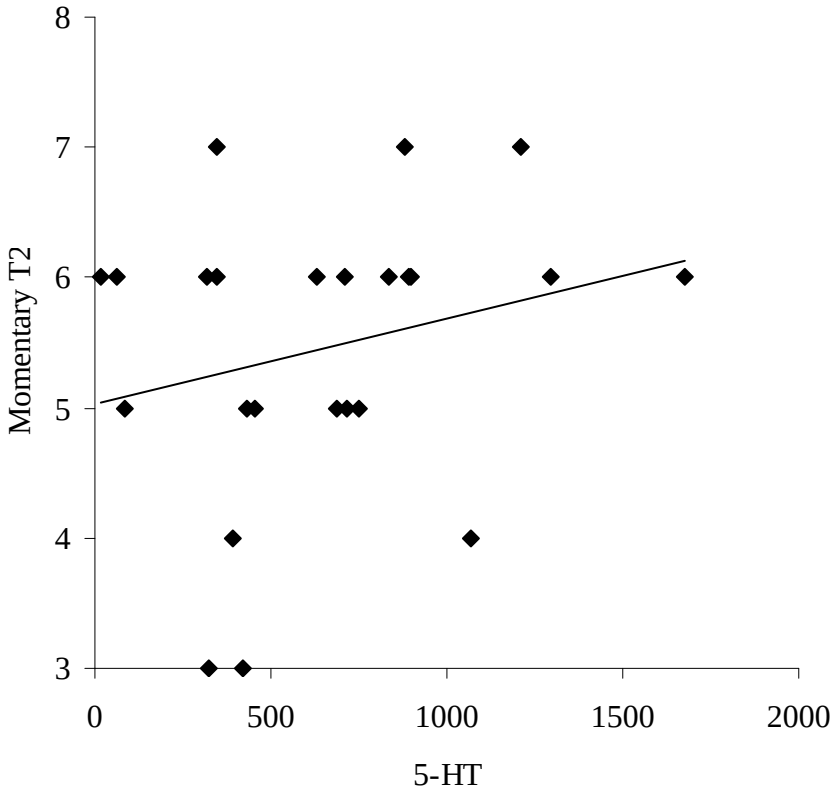


Figure 5

Oxford Happiness Questionnaire score plotted against concentration of urinary 5-HT (ng/ml)

(r = .28; p = .20; n = 23)

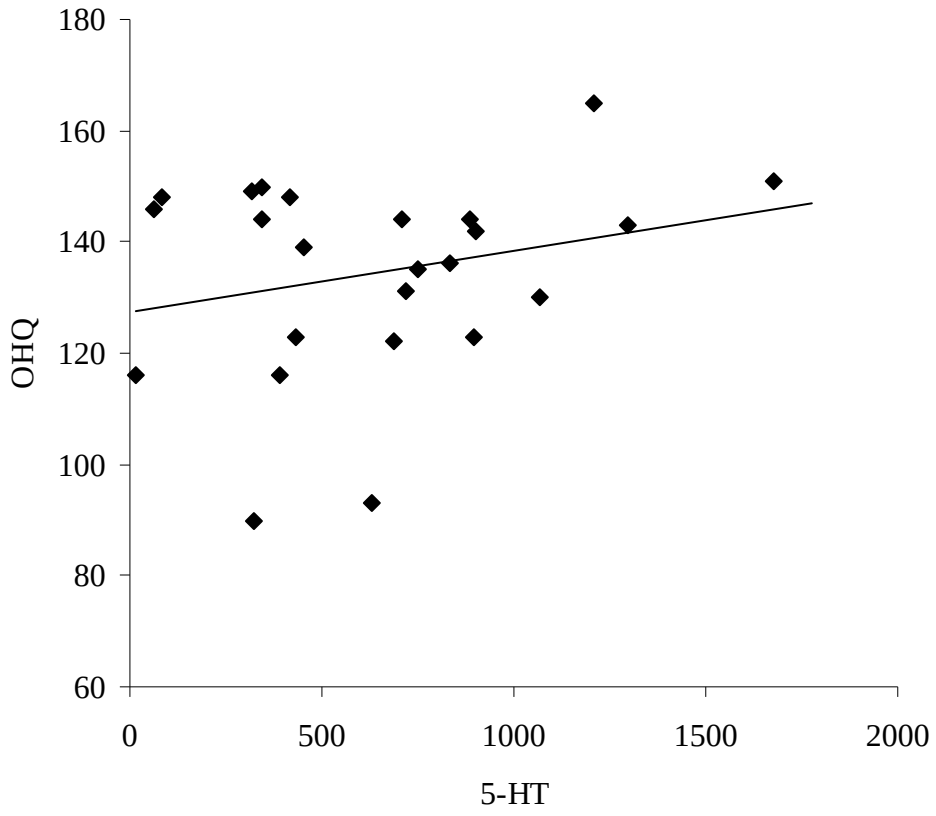


Figure 6

Centre for Epidemiological Studies – Depression Scale score plotted against concentration of urinary BDNF (pg/ml)(r = .10; p = .57; n = 36)

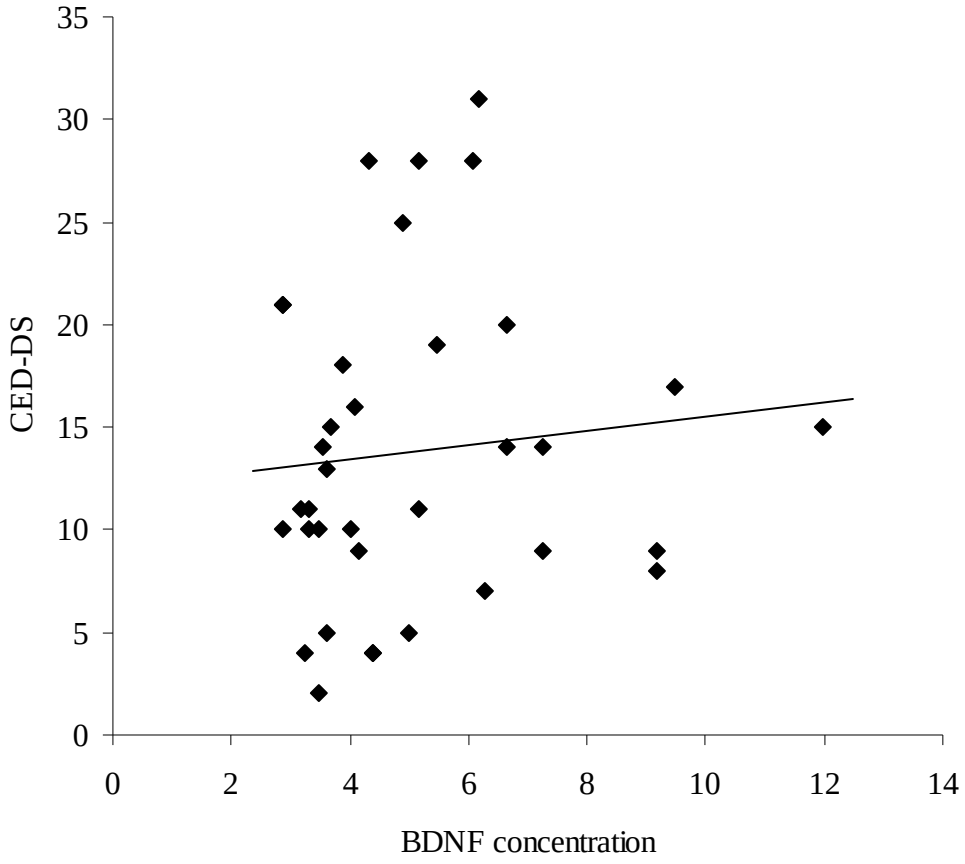
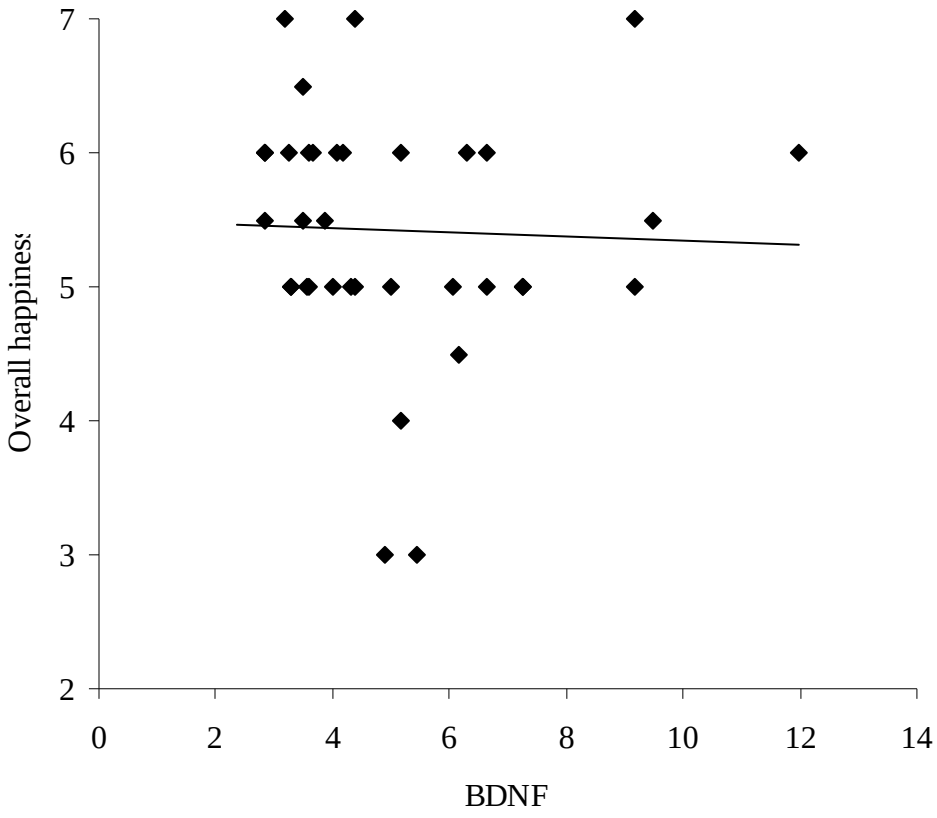


Figure 7

Mean overall T1 and T2 happiness rating plotted against concentration of urinary BDNF (ng/ml) (r = -.04; p = .84; n = 36)



Appendix A

Information Letter and Consent Form

THE UNIVERSITY OF BRITISH COLUMBIA

Irving K. Barber School of Arts and Sciences
3333 University Way
Kelowna, BC Canada V1V 1V7

Information Letter and Consent Form

Title of Study: Physiological Correlates of Happiness and Well Being

Principal Investigator: Dr. Mark Holder, Psychology (250-807-8728).

Co-Investigators: Dr. William Bates (UBCO Professor).

Researchers: Robert Callaway (UBCO graduate student), Ashley Love (UBCO Honours student), and Robyn McAdam (UBCO Honours student), under the supervision of Dr. Holder, will conduct the research. The research will be used for these students' theses.

Support: This research is supported by a grant from the Michael Smith Foundation for Health Research awarded to Dr. Holder.

Purpose: To compare biological assays (urine and saliva) with measures of internal states (happiness, satisfaction, and depression) to study the physiological basis of happiness

Study Procedures: If you agree to participate, you need to sign this consent form. Then a testing time that is convenient for you will be determined. You will be asked to avoid eating certain types of foods (e.g., bananas, pineapple, walnuts, and kiwi) known to affect urinary serotonin levels for one day. You will be asked to provide a urine sample and multiple saliva samples when you wake up on the day of testing (you will be given a bottle to take home and you will be phoned and reminded in the morning). At your testing time, you will complete 5 questionnaires. Four will measure your internal states: two will measure your level of happiness, one will measure your satisfaction, and one will measure your level of depression. The fifth questionnaire will assess demographic (your age and sex) and additional (how often you practice meditation and how healthy you think you are) information. Though this research is not anticipated to put you at any additional risk, for your benefit, a pamphlet on mood and UBCO counseling services will be provided to you.

The entire test should take about 35 minutes of your time.

Confidentiality: Responses of all participants are strictly confidential (individual responses will only be seen by the researchers). Each questionnaire and sample will be coded in order to link the answers from each participant. Only researchers will know this

code. After the data are collected, the codes will be destroyed so individuals cannot be identified. Questionnaires will be kept in a locked room. When the study is completed, all questionnaires will be shredded. We plan to submit the findings for publication. Participants' names will not be used in any reports of the study. The results will only be reported for groups with no possibility of individual participants being identified.

Follow-up: Our findings will be summarized and the results will be posted on Dr. Holder's office door (Arts 328). Public presentations of our results will be made on campus and these will be advertised in advance.

Contact for information about the study: If you have any questions about this study, contact Dr. Mark Holder (250-807-8728).

Contact for concerns about the rights of research participants: If you have concerns about how you and other participants are treated, contact the Chair of Research Ethics Board through the UBCO Office of Research Services (250-807-8150).

Consent: Your participation in our study is completely voluntary and you may refuse to participate or withdraw from the study at any time without penalty

Your signature below indicates that you have received a copy of this form and that you consent to participating in our study.

_____

Participant's Signature Date

_____

Printed Name of Participant

_____

Investigator's Signature Date

_____

Investigator's Printed Name

Appendix B

Faces Scale

THE UNIVERSITY OF BRITISH COLUMBIA

Irving K. Barber School of Arts and Sciences
3333 University Way
Kelowna, BC Canada V1V 1V7

PARTICIPANT NUMBER: _____

DATE: _____

The Physiological Correlates of Happiness and Well Being

Self-Rating of Happiness:

Please fill in the circle below the face, that, overall, best describes how you feel AT THIS MOMENT.

Very Unhappy Very Happy

Please fill in the circle below the face, that, overall, best describes how you feel MOST OF THE TIME.

Very Unhappy Very Happy

Appendix C

Demographic Form

Demographic Information

1. How old are you in years? ____

2. Sex: ___ Male ___ Female

3. Please rate your overall health. *(circle the correct number)*

1 2 3 4 5 6 7

Not Healthy Very Healthy

4. How many times do you meditate each month?
(circle the correct number)

a. 0
b. 1
c. 2-3
d. 6-8
e. 9-15
f. 16+

5. On average, how many minutes do you meditate for each time?

a. 0
b. 1
c. 2-3
d. 4-5
e. 6-10
f. 11-20
e. 21+

Questions 6 and 7 are for females only:

6. Have you been taking oral contraceptives within the last 6 months?

Yes_____ or No ____

7. When was the start of your last menstrual period?
a. This week
b. Last week
c. Three weeks ago
d. Four weeks ago

8. How many cigarettes do you smoke during an average week?
   a. None
   b. 1-5
   c. 6-10
   d. 11-15
   e. 16-20
   f. 21 or more

9. Did you eat any of the foods that you were instructed not to consume in the past 24 hours?

No ____ Yes ____

If yes, what did you eat? _____

Appendix D

Questionnaires

THE UNIVERSITY OF BRITISH COLUMBIA

OKANAGAN

Irving K. Barber School of Arts and Sciences
Psychology and Computer Science

The Oxford Happiness Questionnaire

INSTRUCTIONS: Below are a number of statements about happiness. Would you please indicate how much you agree or disagree with each by entering a number alongside it according to the following code:

1 = strongly disagree;	2 = moderately disagree;	3 = slightly disagree;
4 = slightly agree;	5 = moderately agree;	6 = strongly agree.

You will need to read the statements carefully because some are phrased positively and others negatively. Don't take too long over individual questions; there are no 'right' or 'wrong' answers and no trick questions. The first answer that comes into your head is probably the right one for you. If you find some of the questions difficult, please give the answer that is true for you in general or for most of the time.

1. I don't feel particularly pleased with the way I am

2. I am intensely interested in other people

3. I feel that life is very rewarding

4. I have very warm feelings towards almost everyone

5. I rarely wake up feeling rested

6. I am not particularly optimistic about the future

7. I find most things amusing

8. I am always committed and involved

9. Life is good

10. I do not think that the world is a good place

11. I laugh a lot

12. I am well satisfied about everything in my life

13. I don't think I look attractive

14. There is a gap between what I would like to do and what I have done

15. I am very happy

16. I find beauty in some things

17. I always have a cheerful effect on others

18. I can fit in everything I want to

19. I feel that I am not especially in control of my life

20. I feel able to take anything on

21. I feel fully mentally alert

22. I often experience joy and elation

23. I do not find it easy to make decisions

24. I do not have a particular sense of meaning and purpose in my life

25. I feel I have a great deal of energy

26. I usually have a good influence on events

27. I do not have fun with other people

28. I don't feel particularly healthy

29. I do not have particularly happy memories of the past

THE UNIVERSITY OF BRITISH COLUMBIA

OKANAGAN

Irving K. Barber School of Arts and Sciences
Psychology and Computer Science

Satisfaction With Life Scale

Below are five statements with which you may agree or disagree.
Using the 1-7 scale below, indicate your agreement with each item by filling in the appropriate circle. Please be open and honest in your responding. The 7 – point scale is as follows:

1 = strongly disagree

2 = disagree

3 = slightly disagree

4 = neither agree nor disagree

5 = slightly agree

6 = agree

7 = strongly agree

1. In most ways my life is close to my ideal.

2. The conditions of my life are excellent.

3. I am satisfied with my life.

4. So far I have gotten the important things I want in life.

5. If I could live my life over, I would change almost nothing

THE UNIVERSITY OF BRITISH COLUMBIA

OKANAGAN

Irving K. Barber School of Arts and Sciences
Psychology and Computer Science

Center for Epidemiological Studies Depression Scale

Circle the number of each statement which best describes how often you felt or behaved this way – DURING THE PAST WEEK.

DURING THE PAST WEEK:	Rarely or none of the time (Less than 1 day)	Some or a little of the time (1 -2 days)	Occasionally or a moderate amount of the time (3-4 days)	Most or all of the time (5 – 7 days)
1. I was bothered by things that don't usually bother me				
2. I did not feel like eating; my appetite was poor				
3. I felt that I could not shake off the blues even with help from my family or friends				
4. I felt that I was just as good as other people				
5. I had trouble keeping my mind on what I was doing				
6. I felt depressed				
7. I felt that everything I did was an effort				
8. I felt hopeful about the future				
9. I thought my life had been a failure				
10. I felt fearful				
11. My sleep was restless				
12. I was happy				
13. I talked less than usual				

14.	I felt lonely	_	☐	☐	◂
15.	People were unfriendly	_	☐	☐	◂
16.	I enjoyed life	_	☐	☐	◂
17.	I had crying spells	_	☐	☐	◂
18.	I felt sad	_	☐	☐	◂
19.	I felt that people disliked me	_	☐	☐	◂
20.	I could not get “going”	_	☐	☐	◂

Self-Rating of Happiness:

Please fill in the circle below the face, that, overall, best describes how you feel AT THIS MOMENT.

Very Unhappy Very Happy

Please fill in the circle below the face, that, overall, best describes how you feel MOST OF THE TIME.

Very Unhappy Very Happy