NEUROSCIENTIFIC PERSPECTIVE ON THE BIDIRECTIONAL RELATIONSHIP BETWEEN LIFE SATISFACTION AND HEALTH
Are people happier because they are healthy, or are they healthier because they are happy?

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Markus Niemi

Supervisor: Petri Kajonius
Examiner: Paavo Pylkkänen
Abstract

Bentham’s 1832 Greatest Happiness Principle states that the greatest happiness for the greatest amount of people should be the goal of public policy. When people are asked what they wish for in life, health and happiness are consistently mentioned. This thesis examines the relationship between health and happiness. However, as happiness is difficult to consistently operationalize across different studies and scientific disciplines, life satisfaction is used as a proxy for happiness. This thesis studies the relationship between health and life satisfaction with a particular focus on the directionality of the relationship and the tentative processes indicated to be involved with this process. This study is accomplished through a literary review of the scientific literature related to life satisfaction, its neural correlates and their relationship with physical health. This study is modelled on the top-down, bottom-up and bidirectional debate within the larger Subjective Well-Being (SWB) literature. The results indicate that the correlation between life satisfaction and health appears to be robust, but the exact directionality and causality is unclear and difficult to establish with a literary review, with only predictive ability of life satisfaction on later physical health or vice versa established. Furthermore, the results appear to indicate that the central process linking this relationship is resilience - the ability to adaptively respond to stressors. Enhancing resiliency through psychological interventions may be a method to promote happiness and health in individuals as well as in society as a whole.

Keywords: neuroscience, life satisfaction, happiness, health, resilience, behavioural changes, public happiness, public health
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Introduction

Happy people tend to live longer and enjoy better health, in comparison to unhappy people. Are these people happier because they have better health, or do they have better health because they are happier? This is an important question, especially when contrasted with Jeremy Bentham’s greatest happiness principle that states that the goal of all public policy should be the greatest happiness for the greatest amount of people (Bentham, 1823). However, as happiness is difficult to operationalize in terms of scientific research, life satisfaction can be used as an acceptable proxy for chronic or long-term happiness (Veenhoven, 2010). If life satisfaction is used as a proxy for happiness, the scientific literature appears to show that people who are satisfied with their lives appear to live longer and experience fewer adverse health episodes than people who are dissatisfied with their lives (Diener & Chan, 2011; Koivumaa-Honkanen et al., 2000).

This would appear to provide evidence for a link between life satisfaction and improved health. But how does this link function? What neural processes in the brain enable the bodies of more satisfied people to be healthier? In order to examine this relationship, the concepts of both life satisfaction and health first need to be more stringently defined. “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”, according to the World Health Organization (WHO) (World Health Organization, pg. 1, 2006). However for the purpose of exploring the role of happiness in health, this definition is too wide as it also includes psychological health. For this reason the definition that health is complete physical well-being will be used instead for this thesis. While this definition will be the primary focus of this thesis, psychological conditions with clear physical symptoms such as depression to be conditions that infringe upon an individual’s health will also be considered to be included in physical health.
If the relationship between happiness and health is explored from a longitudinal perspective, the literature indicates that the most suitable metric for happiness appears to be life satisfaction (Veenhoven, 2017). Life satisfaction is defined as a subjective cognitive assessment of how satisfied an individual is with his or her life (Diener, 1994). This can be considered to be a suitable metric for long-term happiness, as life satisfaction is steady over longer period of time as a cognitive assessment, in contrast with affective measures that tend to vary over time and depending on circumstance (Kong et al., 2014). Life satisfaction can also be stated to be more appropriate metric for literature review as it has a mostly consistent definition across scientific fields while the definition of happiness varies.

If these definitions are used, then the relationship between a relatively stable indicator of happiness with consistent definition across different articles and physical health can be examined in detail from a neuroscientific perspective. In addition to examining the directionality of this relationship, this perspective focuses on neural processes in the brain. If the neural correlations for life satisfaction and the processes they use to effect health can be identified, then these findings can provide valuable guidance on how to implement both psychologically and neurally based interventions that enhance a person’s life satisfaction (Kong et al., 2014) and health. This is particularly beneficial if these interventions may be used on a larger population with regards to the available resources and interventions.

This is an important field of study, if consideration is given to the greatest happiness principle and utilitarian philosophy. In defending Bentham’s principle of utilitarianism, Veenhoven notes in her 2017 article that if the greatest happiness is defined as life satisfaction, a subjective appreciation of life in general over a longer period, then Bentham’s principle becomes appropriate for several reasons (Veenhoven, 2017). One of these reasons is that life satisfaction is associated with longevity and health, and so, by encouraging the greatest life satisfaction for the greatest amount of people, health and longevity would be
encouraged as well. In contrast, evidence has been provided for the association between life dissatisfaction, mortality and behaviour adverse to health such as smoking or excessive use of alcohol (Koivumaa-Honkanen et al., 2000). Therefore the evidence would also seem to suggest that if similar interventions may be used to improve life satisfaction or even prevent dissatisfaction. This would in turn also indirectly improve health, or at the very least stave off the worst symptoms of adverse health episodes.

In summary, if the neural biological relationship between life satisfaction and physical health and the processes effecting this relationship are examined in more detail, the findings may provide indications for interventions that would improve both life satisfaction and health. This would enable the enhancement of an individual’s health in a holistic manner, in conformity to the definition of health according to the WHO.

**Methodological Approach**

The aim of this thesis is to study the bidirectional relationship between life satisfaction and health from a neuroscientific perspective. The specific focus of this thesis will be to provide the reader with an overview of the scientific evidence on both the primary directionality and the processes behind this relationship from a neural perspective.

For the purpose of clarifying this study the directionality in the relationship will be defined in three different ways; Top-Down Effect, Bottom-Up Effect and Bidirectional Effect. These definitions are primarily based on the discussion within the scientific literature on whether life satisfaction is a result of a top-down or a bottom-up process. For the sake of clarifying the discussion, this thesis will refer to the directionalities of effect in the following way:

- **Top-Down Effect**: The primary effect is from life satisfaction to health that higher life satisfaction provides an improvement to physical health.
• Bottom-Up Effect: The primary effect is from health to life satisfaction and as such life satisfaction is partially an indicator of an over-all physically healthy experience.

• Bidirectional Effect: There is overlap in the effects of the top-down and the bottom-up effects, in that higher life satisfaction does improve health, but also that high life satisfaction is partially based on positive subjective health. As such, neither direction of effect has a primary role.

**Thesis Composition**

Life satisfaction will be first scientifically defined based on the available literature and then examine the factors that have been implicated in the formation of life satisfaction, before examining the neural correlates of life satisfaction. Then the available scientific evidence for the relationship between life satisfaction and health will be explored. Then the possible processes in Top-Down, Bottom-Up and Bidirectional effects are examined.

Finally, the topic of this thesis will be discussed, based on a review of the published scientific articles within the field, and in particular by focusing on review articles that collate data from several studies to ensure that this thesis bases its discussion on scientific evidence from a sufficiently large experimental population. Further evidence from original neuroscientific or medical articles for neuronal and other biological evidence will be presented. The discussion will further include the practical implications of the presented scientific data, the limitations of the thesis and the consequent evidence as well as suggested areas for future research. A brief summarizing conclusion will be provided at the end of the discussion.

**Theoretical Background**

The scientific definition of life satisfaction, or satisfaction with life, used in this thesis is primarily based on the works of Diener and his Subjective Well-Being (SWB) theory
In this theory, Diener states that life satisfaction forms the cognitive part of well-being that together with the presence of positive affect and the absence of negative affect forms SWB (Diener, 1994). Kahneman’s work, especially his differentiation of experienced well-being and evaluated well-being (Kahneman & Riis, 2012) is used as a secondary source of information for the purpose of definition. The subjective cognitive evaluation behind life satisfaction has been closely correlated with positive affect but is not necessarily a purely hedonic state, as it may also include more eudaimonic aspects (Sato et al., 2015). In practice, this means that while an individual who is satisfied with his or her life may experience extensive positive affect that the state of being satisfied with life is not an affective state, even though this cognitive assessment may in certain circumstances stimulate further positive affect.

The discussion of whether life satisfaction and health have a top-down, bottom-up or a bidirectional relationship is primarily based on the discussion within the SWB literature that has in the past debated, and continues to debate the determinants of a person’s reported life satisfaction (Leonardi, Spazzafumo, Marcellini, & Gagliardi, 1999; Nakazato, Schimmack, & Oishi, 2011). The available literature has indicated a possibility that life satisfaction, as a part of SWB, may be formed according to a top-down model, a bottom-up model or possibly a model that combines effects from both directionalities. Therefore this thesis will approach the directionality question by considering that life satisfaction and health may have a similar relationship in terms of directionality as SWB and life circumstances in general.

**Life Satisfaction and Associated Constructs**

Life satisfaction forms the cognitive part of Diener’s SWB-model (Diener, 1994; Kong, Wang, Hu, & Liu, 2015), and as such, life satisfaction is often considered to be a form of hedonic emotional well-being with a strong cognitive component that is closely linked with the other parts of SWB, the presence and intensity of positive and negative affect.
As such, it can be said that life satisfaction is a form of affective happiness based on a subjective cognitive assessment that is closely and robustly associated but independent from the total hedonic levels of positive and negative emotions (Busseri, 2018).

Although the debate continues in the literature on whether life satisfaction is a purely cognitive judgement or if it has an affective dimension as well (Lyubomirsky, King, & Diener, 2005). However, it should be noted that especially in certain more collectivistic cultures in Eastern Asia that life satisfaction may also have a more eudaimonic component that implies a more subjectively meaningful aspect to life satisfaction (Sato et al., 2015). As such, the indication appears to be that there may be a cultural aspect in life satisfaction.

However, evidence is presented that the self-reported levels of life satisfaction are affected by relatively irrelevant circumstances such as weather at time of the testing (Diener, 1994). Further experiments indicated that this effect can be controlled or at very least attenuated for by the experimenter by calling the participants’ attention to them (Diener, 1994). The scientific evidence in general indicates that life satisfaction is relatively stable construct, as measurements with the Satisfaction With Life Scale (SWLS) have shown stability coefficients of over 0.80 over a period of several weeks (Diener, Inglehart, & Tay, 2013).

In a longitudinal twin study in Finland with 9679 participants, life satisfaction in an adult population was found to be moderately stable over a period of 15 years with a correlation $r = 0.30-0.40$ between continuous scores (Koivumaa-Honkanen, Kaprio, Honkanen, Viinamäki, & Koskenvuo, 2005). This same study also identified that with those whom self-report themselves to be dissatisfied with life, this dissatisfaction may become a persistent, chronic condition (Koivumaa-Honkanen, Kaprio, Honkanen, Viinamäki, & Koskenvuo, 2004). In their interpretation of the results of the study, the authors provide evidence to suggest that baseline life dissatisfaction may be used to predict future
dissatisfaction as well (Koivumaa-Honkanen, Kaprio, Honkanen, Viinamäki, & Koskenvuo, 2004). Furthermore, the study identified that both age and birth cohort have slight effects on life satisfaction (Koivumaa-Honkanen et al., 2004). However, it should be noted that because all of the participants in this study were born and raised in the same country that there may be possible cultural, societal or even possible biological variables due to the relatively homogenous population that may prevent the results from being fully generalized to a global population.

Different measurements of life satisfaction have been observed to have a moderate-to-high correlation ($r < 0.30$) (Diener et al., 2013), providing evidence for the validity of the life satisfaction as a construct to measure a form of subjective well-being. Furthermore, self-rated life satisfaction has been also found to be correlated with peer estimated life satisfaction in two different studies with rates of $r = 0.54$ and $r = 0.64$ respectively (Diener, 1994). Therefore, the available evidence would seem to support life satisfaction being used as a valid, longitudinally stable reliable proxy for long-term chronic happiness (Lyubomirsky et al., 2005; Veenhoven, 2017) or for long-term unhappiness in the case of life dissatisfaction. Furthermore, self-rated questionnaires of life satisfaction can provide a large amount of scientific data by that they are a non-intrusive method that can be relatively cheaply administered to a large population, especially when other measurements are unavailable or inappropriate to use.

The construct of Quality of Life (QOL) is defined by the World Health Organisation Quality of Life (WHOQOL) as an individual’s subjective perception of their position in their life, in the context of their culture and value systems in regards to their expectations, standards, goals and concerns and is a closely related, convergent concept to life satisfaction (The WHOQOL Group, 1995). It can be even said that life satisfaction forms a part of the QOL construct (Camfield & Skevington, 2008; The WHOQOL Group, 1995), and in the past,
life satisfaction has been indicated to be an acceptable social indicator for QOL (Camfield & Skevington, 2008). As such, due to the high convergence and overlap between the definitions of QOL and life satisfaction (Camfield & Skevington, 2008), a closer examination of the factors behind the subjective evaluation of QOL and its neural correlates may provide further clues for the antecedents of life satisfaction and its neural correlates.

The Factors of Assessing Life Satisfaction

The judgement of how satisfied or dissatisfied an individual is with his or her life is a complex subjective cognitive appraisal that is based on a number of factors such as level of income, self-observed health status both physically and mentally, employment status, satisfaction with work and social comparison (Lent, 2004). Certain populations low on these factors, such as psychiatric patients, the unemployed (Koivumaa-Honkanen et al., 2004), sex workers and prisoners (Diener et al., 2013) have consistently self-reported lower satisfaction with life, while the independently wealthy consistently report higher satisfaction (Diener et al., 2013). Income appears to be correlated with life satisfaction with the extremely wealthy and the extremely poor (Diener, Oishi, & Lucas, 2003). Levels within the factors of income, health and education could be used to accurately predict an average level of life satisfaction (Diener et al., 2013). However this prediction could not be generalized to a more global population due to the limited nature of the sample population in the studies (Diener et al., 2013, 2003).

The available data would appear to suggest that culture plays a significant role in the formation of life satisfaction, as countries with a roughly similar level of development such as Japan and Denmark consistently rate their life satisfaction on different levels; 6 for Japan versus 8 for Denmark, on a scale from 0-10 (Diener et al., 2003). This would appear to indicate that cultural influences may, at the very least, influence the baseline level of satisfaction. It would appear that cultural factors provide on average a 12% variance on life
satisfaction (Diener et al., 2003). Even factors that at first glance have only small correlations with life satisfaction such as marriage or religion may in the long term provide enhancement to life satisfaction through processes such as providing a sense of eudemonic meaning (as in the case with religion), through the social support functions such as material aid or emotional support in the case of marriage (Lent, 2004). In the case of marriage, the argument can be made that the quality of the relationship is more important than marital status (Ryan & Deci, 2001). However, these factors can be grouped together as demographic factors and account for 8-15% of the variance in life satisfaction (Lent, 2004).

Further evidence from other studies appears to suggest that up to 80% of life satisfaction may be due to genetic traits, but this has been debated on the grounds that families that are more frequently satisfied with their lives share environmental traits as well as genetic factors (Lent, 2004). Twin-design studies have provided contrasting evidence that indicates that family environment shows a close to 0% variance in life satisfaction (Lent, 2004). The debate furthermore raises the point that while life events may produce short term fluctuations in a baseline life satisfaction that may be otherwise based on a more stable personality trait or disposition (Lent, 2004).

In the short term, recent life events do appear to strongly correlate with reported life satisfaction (Diener, Suh, Lucas, & Smith, 1999). However, the evidence can be interpreted to support an argument for a stable, dispositional trait to life satisfaction that produces a baseline satisfaction; more satisfied people tend remain satisfied in the long term, and dissatisfaction may become chronic with those already dissatisfied (Koivumaa-Honkanen et al., 2005; Lent, 2004). Evidence suggests that the trait of extraversion and self-esteem have been found to be positively correlated with life satisfaction, while neuroticism has been found to be negatively correlated with life satisfaction (Kong et al., 2014; Lent, 2004; Mroczek & Spiro, 2005). Findings also suggest that personality traits, particularly along the introversion-
extroversion axis affect life satisfaction, especially if the effects from the environment and personality compound each (Mroczek & Spiro, 2005). As such, the evidence would seem to suggest that personality traits and heritability may have a large impact on life satisfaction.

A study that examined the life satisfaction of 1927 male participants over a period of 22 years furthermore found evidence to suggest that self-rated life satisfaction is correlated with age, peaking at approximately 65 years of age, but on average declining after that point (Mroczek & Spiro, 2005). However, the limitations of this study must be noted – the test population was relatively homogenous with everyone in the population sharing both a cultural and an occupational background as American military veterans and as such the results may reflect variables that make it difficult to generalize to a more global population or to a population from a different cultural setting.

**Neural Correlates of Life Satisfaction**

The neural correlates of life satisfaction in healthy individuals have only been studied in a limited amount of neuroscientific studies, and only one study has directly neuroanatomically studied a possible process behind the relationship between life satisfaction and health. This thesis will therefore present the studies that have directly examined the neural correlates of life satisfaction or other closely related constructs such as Quality of Life as defined by the WHOQOL as a foundation to examining the processes that affect the relationship between health and life satisfaction.

A study that utilized functional Magnetic Resonance Imagining (fMRI) in a structural MRI together with measures that evaluated the cognitive side of happiness – life satisfaction, according to their definition – identified that gray matter volume in the right precuneus was associated with life satisfaction when life satisfaction was defined to include a purposeful eudaimonic component (Sato et al., 2015) Their results appear to suggest that the precuneus
is responsible for mediating subjective happiness by integrating the cognitive and emotional components of happiness (Sato et al., 2015).

Another fMRI study on 290 Chinese university students that had their life satisfaction measured with the SWLS scale and self-esteem assessed using the Rosenberg Self-esteem scale (RSES) before using fMRI to examine the anatomy of their brain. The results suggested that life satisfaction was significantly and negatively associated with grey matter volume (GMV) in the left ventro-medial pre-frontal cortex (vmPFC) as well as in an anatomical cluster that included the left precuneus (Kong et al., 2014). Life satisfaction was indicated to be positively correlated with GMV in the right parahippocampal gyrus (PHG) (Kong et al., 2014).

However, the same study also found that self-esteem was correlated with GMV in the right PHG and negatively correlated with GMV in the left precuneus (Kong et al., 2014). Once the anatomical correlates for life satisfaction were controlled for the mediating effect of self-esteem, it was found that self-esteem partially mediated the association between PHG volume and fully mediated the association between the precuneus and life satisfaction (Kong et al., 2014). According to the findings of this study, there is a close relationship between these neural areas but the exact nature of this relationship remains unclear, though the evidence does suggest that self-esteem does play a significant role in the development of life satisfaction (Kong et al., 2014). It should be noted that this study used the relationship between life satisfaction and self-esteem as a significant part of its theoretical background, and thus may focus on the neural correlates of self-esteem to the exclusion of the neural correlates of other factors such as extroversion or neuroticism. Corroborating evidence from another source seems to suggest that the precuneus plays a role by engaging in mental representations of self-related mental together with the default-mode network during rest (Kringelbach & Berridge, 2017).
A fMRI study explored the roles of spontaneous fractional amplitude of low frequency fluctuations (fALFF) in the brain in correlation to cognitive subjective well-being, which the study defined as life satisfaction (Kong, Hu, Wang, Song, & Liu, 2015). The study examined 294 Chinese university students whose level of life satisfaction was measured with SWLS before they were examined using fMRI (Kong, Hu, et al., 2015). The results indicated that cognitive well-being was positively correlated with fALFF in the right posterior mid-cingulate cortex (pMCC), positively linked with fALFF in the left postcentral gyrus (PCG), lingual gyrus, the right thalamus and left planum temporale (PT) (Kong, Hu, et al., 2015). The study also found that life satisfaction was negatively correlated with fALFF in the prefrontal cortices, including the right orbitofrontal cortex (OFC) and bilateral superior frontal gyrus (SFG) and negatively linked with fALFF in the left inferior temporal gyrus (ITG) (Kong, Hu, et al., 2015). The conclusion of the study indicates these areas are associated with sensation, cognition, social perception and emotion (Kong, Hu, et al., 2015). The study also theorized that emotional intelligence may be important to the formation of life satisfaction (Kong, Hu, et al., 2015). However, it should be noted that all three of these studies used University students from a limited age and geographical range and such there may be biological or cultural background variables in the results that prevent them from being generalized to a large population.

A study utilizing electroencephalography (EEG) examined 84 adults in the age range from 57 to 60 years old, after recording their levels of both hedonic with SWLS and the Positive Affect Negative Affect Schedule (PANAS) and eudaimonic well-being with the Scales of Psychological Well-Being (PWB) (Urry et al., 2004). After correcting for eye movement and muscle artifacts, the results indicated that there may be a modest but robust relationship between activation in the posterior region of the superior frontal cortex and both eudaimonic and hedonic well-being (Urry et al., 2004). However, it should be noted that this
A study that studied the neural correlates of QOL, as defined by the WHOQOL, on 159 university students or postgraduates in Japan with MRI, found that higher QOL – and thus by extension possibly higher life satisfaction – was found to be correlated with decreased GMV in the dorsal anterior cingulate gyrus (dACG), as well as associated cingulate regions, and the left rostrolateral prefrontal cortex (rlPFC) (Takeuchi et al., 2014). These regions are found to be consistently activated when pain is felt and the regions are found to be correlated with functions such as cognitive controls and the reinforcement of learning (Takeuchi et al., 2014). The study theorizes that the lower functioning of this area may be associated with experiencing fewer negative emotions and may lead to higher life satisfaction (Takeuchi et al., 2014).

When the relationship between life satisfaction and the hedonic pleasure network of the brain is examined, the researchers conducted a review study the various hedonic hotspots – dorsal anterior cingulate cortex (dACC), frontal anterior cingulate cortex (fACC), rostral anterior cingulate cortex (rACC), medial orbitofrontal cortex (mOFC), inferior orbitofrontal cortex (iOFC), midanterior orbitofrontal cortex (midOFC), periaqueductal grey (PAG) in the brain during the different phases of the pleasure cycle (Kringelbach & Berridge, 2017). In the results, the study hypothesizes that optimal metastability in the brain’s affective network is correlated with a state of subjective satisfaction with life (Kringelbach & Berridge, 2017). The study further finds that the subjective feeling of long term well-being and a sense of satisfaction may be related to the ‘liking’ state of the pleasure network in the brain more so than it is with the ‘wanting’ state of the network (Kringelbach & Berridge, 2017). Another study by the same scientists also indicated that the default-mode network may be related to
connecting short term affective happiness with longer term cognitive well-being, such as life satisfaction (Kringelbach & Berridge, 2010).

The Theoretical Relationship Between Life Satisfaction and Physical Health

Health status is moderately positively correlated with life satisfaction ($r = 0.36$), even more so than how it is correlated with SWB operationalized as affective happiness ($r = 0.31$) (Ngamaba, Panagioti, & Armitage, 2017). This correlation does not differ significantly when objective or subjective measures are used to establish health status, or when healthy individuals and individuals with chronic medical conditions are included in the study (Ngamaba et al., 2017). The correlation was found to be stronger in two cases as well; in studies carried out in developing countries and studies that utilized multiple item measures in contrast to studies that used single-item measures (Ngamaba et al., 2017).

Life satisfaction is also correlated with longevity in general, even when controlled for marital status, social class, physical activity, and smoking, as results from the Finnish Twin Cohort Study (FTCS) indicate (Koivumaa-Honkanen et al., 2000). The study also indicated that life dissatisfaction was also correlated with increased age-adjusted mortality; as well as male disease mortality after controlling for the variables listed above (Koivumaa-Honkanen et al., 2000). As such, the study in total would appear to indicate that life satisfaction is associated with longevity and beneficial health behavior, while life dissatisfaction is associated with the opposite (Koivumaa-Honkanen et al., 2000).

However, it would appear that this correlation may be different in different age groups, as a study indicated that with individuals older than 65 years old, both genetic and environmental effects contribute substantially to the relationship between health and life satisfaction, while with younger group the association could be entirely environmental (Røysamb, Tambs, Reichborn-Kjennerud, Neale, & Harris, 2003). The results of a study
carried out on 3288 pairs of Norwegian twins indicate that life satisfaction is substantially related to subjective health, that is to say, health as observed by the individual and moderately and negatively related to observed pain and in practice unrelated to allergic disorders (Røysamb et al., 2003). This same study also indicated that there is evidence of an overlap in the genetic predispositions for life satisfaction and subjective health (Røysamb et al., 2003).

Studies have indicated that life dissatisfaction can be used for predicting chronic pain syndrome and it would appear that some of the evidence indicates that life dissatisfaction contributes to immune system downregulation, and as such, would seem to predict some physical illnesses in both healthy individuals and those with pre-existing conditions (Frisch, 1998). Contrasting evidence is provided by a study that examined the effect of life satisfaction with hemodynamic reactivity in a group of 86 men (Schwerdtfeger, Gaisbachgrabner, & Traunmüller, 2017). The results indicated that life satisfaction was correlated with beneficial hemodynamic reactivity, meaning that individuals who were more satisfied with their lives could cope with physical stress more adaptively (Schwerdtfeger et al., 2017). As such, the indication appears to be that higher life satisfaction is not only correlated with improved physical health and that adaptive physical reactivity may be one of the processes behind this relationship.

A review study further illustrates that in two separate longitudinal studies, in a Scandinavian twin study with 380 participants, found that life dissatisfaction was correlated with almost doubled risk for mortality when compared to high satisfaction (Diener & Chan, 2011). A 3 year longitudinal study of 9981 adult Australians found that high life satisfaction was correlated with better physical health at the 2 years follow-up in addition to a relative absence of long-term adverse health effects (Diener & Chan, 2011). The review study furthermore concluded that the effect size for the relationship between life satisfaction and
physical health in healthy population was variable, depending on the population studied, but significant enough that it should feature more in political societal decision making (Diener & Chan, 2011).

In summary, it would appear that the consensus in the available literature is that life satisfaction is correlated with physical health, but questions remain over the directionality of the relationship.

Directionality

While the consensus appears to be to that there is a robust relationship between life satisfaction and health, the debate continues on the directionality of this relationship similarly to how life satisfaction itself is formed (Feist, Bodner, Jacobs, Miles, & Tan, 1995; Leonardi, Spazzafumo, & Marcellini, 2005). On one side of the debate, the literature supports the position that high life satisfaction (along with the other parts of SWB) can improve an individual’s longevity and aid in preventing or healing disease (Diener & Chan, 2011). This is frequently asserted especially within the realm of positive psychology that supports the idea that enhancing life satisfaction and happiness will lead to enhancements in other areas of life (Lyubomirsky et al., 2005). A review study indicated that there is convergent evidence from a number of different methodologies, ranging from quasi-experimental interventions to physiological studies that show that mood and emotions are associated with positive health outcomes (Diener & Chan, 2011). Randomized controlled intervention studies to build a strong case to support the argument that SWB in total (and not just life satisfaction) causally influences health and longevity (Diener & Chan, 2011). However, as this review article discusses the effect of SWB in total and not just life satisfaction, it may be that the affective components of SWB provide an effect that life satisfaction alone cannot provide.

In contrast, the literature supports the argument that higher life satisfaction is based in part of continued health, and that life satisfaction has no effect on mortality or physical
health, but acts rather as an indicator of continued healthy experience (Gana et al., 2013). A longitudinal study on 899 participants ranging from 64 to 97 years in age, with assessments 5 times over an 8 year period found that after cross-lagged and simultaneous models were specified and analyzed that poor health significantly predicted life dissatisfaction (Gana et al., 2013). The results of the study indicate that all correlational paths from health to life satisfaction were significant ($r = -0.15$ to $r = -0.18$), but none of the paths from life satisfaction to health were ($r = -0.03$), and such, the effect of health on life satisfaction indicated a medium effect (Gana et al., 2013). This has been further supported by the evidence that adverse health episodes or health-related problems have been observed to lower a person’s measured life satisfaction or subjective quality of life (Takeuchi et al., 2014). Other evidence indicates that biological factors, such as genetic predisposition on personality traits such as extraversion or neuroticism, may further have a significant effect on the formation of life satisfaction (Kajonius & Carlander, 2017), thus further indicating that biological and genetic factors may have a significant effect on life satisfaction.

However, as the vast majority of the studies are longitudinal studies that examine the association over a longer period of time are by definition unable to firmly establish causality, this thesis will also discuss the possibility of a third directionality in the bidirectional effect that combines top-down effects with bottom-up effects.

**Processes in the Relationship Between Life Satisfaction and Health**

This section of the thesis will present and examine processes implicated in the available literature based on what primary directionality the process has been indicated to function in. However, it should be noted that these processes are abstract constructs of more complex biological processes and as such are only used to present tentative primary directionality of effect, based on which directionality of effect the process presents. In
practice these processes may well possess a more intricate function in addition to a complex total directionality.

**Top-Down Effect Processes**

The Top-Down Effect states that life satisfaction has a significant effect on physical health. This effect is in particular supported by positive psychology that suggests that improving an individual’s life satisfaction and happiness may also lead to improvements in other areas of the individual’s life such as health (Diener & Chan, 2011; Lyubomirsky et al., 2005). Furthermore, positive psychology also suggests that this improvement may be particularly strong in coaching and therapy processes that utilize positive psychology and other forms of cognitive interventions (Frisch et al., 2005; Seligman, 2007).

In this direction of effect, the following processes are the result of the individual’s subjective experience of life satisfaction. These processes may improve the individual’s health directly through a process such as a stronger analgesic placebo response (Pecina & Zubieta, 2015) or fewer health adverse psychosomatic symptoms (Al-windi, 2005; de Waure et al., 2015). Other processes may function indirectly by reinforcing health positive changes in behaviour and discouraging negative health behaviour (Koivumaa-Honkanen et al., 2005; Veenhoven, 2017) or improving the individual’s psychosocial conditions in a way that is more conductive to health (Kringelbach & Berridge, 2010).

**Placebo effect on experienced pain intensity.** A study of 45 healthy volunteers found that life satisfaction can partially predict the strength of placebo analgesic (Peciña et al., 2013). This study indicated, partially, that people who were satisfied with life as a trait had a greater reduction of experienced pain intensity (Peciña et al., 2013). This reduction of pain intensity was found to be negatively correlated with neuroticism as a trait (Peciña et al., 2013). It should be noted that neuroticism has been indicated to be negatively correlated with life satisfaction. Further examination of the analgesic placebo effect by positron emission
tomography (PET) found that the cognitive and emotional processes activated by the administration of placebo appear to be associated with the neurobiological processes of resilience (Pecina & Zubieta, 2015). This is corroborated by evidence that indicates that satisfaction with life is associated by lesser grey matter volume in areas of the brain that are traditionally associated with the subjective experience of pain (Takeuchi et al., 2014). In summary, the evidence would appear to indicate that individuals who are more satisfied with their lives would appear to subjectively experience less intense pain.

**Fewer adverse psychosomatic symptoms.** A study that examined a population of 470 adults in Sweden for the relationship between life satisfaction, somatic symptoms and self-perceived health found that life satisfaction was strongly associated with perceived health and negatively associated with psychiatric and somatic conditions (Al-windi, 2005). However, the study indicated that life satisfaction was more negatively correlated with psychiatric than somatic conditions (Al-windi, 2005). This would indicate in practice that life satisfaction acts a protective component against the onset of both adverse psychological and physical symptoms, and as such, directly improves health by acting as a protective process.

Another study that examined 8516 Italian university students found that higher life satisfaction was associated with better self-reported physical health, however the female participants reported more somatic and psychological symptoms than the male ones with a similar rated life satisfaction (de Waure et al., 2015). As such, the evidence appears to corroborate the finding of the Swedish study and further implies that there may be gender-related differences in how life satisfaction affects physical health, though such suggestions should be only cautiously made. In summary, the evidence would appear to suggest that satisfaction with life acts as a protective process against adverse physical or psychological somatic symptoms.
**Behavioural changes.** Theoretical evidence indicates that life satisfaction acts as a positive subjective signal to the individual that his or her behaviour and environment are positive and conducive to continued health and happiness (Veenhoven, 2017). As such, the experience of life satisfaction acts as a beneficial signal that reinforces current behaviour, whereas dissatisfaction works as an inhibitory signal that indicates that current behaviour is not adaptive (Veenhoven, 2017). Life satisfaction has been found be correlated with decisions that are often associated with behaviour that is more beneficial to health such as regular exercise (Koivumaa-Honkanen et al., 2000). In contrast, life dissatisfaction has been found to be associated with behaviour that is detrimental to health such as heavy alcohol use or regular smoking (Koivumaa-Honkanen et al., 2000). As such, the evidence appears to indicate that subjective life satisfaction acts as a signal to reinforce adaptive behaviour. This argument is further supported by a review study that indicates that long-term life satisfaction, defined as chronic happiness is often associated with adaptive behaviour (Lyubomirsky et al., 2005).

However, contrasting evidence is provided by a study on 1289 patients with cardiovascular diseases on the relationship between life satisfaction and behavioural changes in the context of cardiovascular disease prevention (Baumann, Tchicaya, Lorentz, & Le Bihan, 2017). This study indicated that while the hopes for a higher life satisfaction may facilitate a higher intention to change behaviour, the perceived unpleasantness of the new healthier behaviour may prevent adopting the new behaviour (Baumann et al., 2017). Furthermore, this study indicates that if adaptive behaviour changes are forced upon a person, no matter the benefit of the change in behaviour, the person’s life satisfaction will decrease as a result (Baumann et al., 2017). In summary, the evidence would appear to indicate that the experience of being satisfied with life may reinforce health beneficial behaviour and
dissatisfaction may encourage the termination of health adverse behaviour, though this may be confounded by additional psychological factors.

Psychosocial factors. Theoretical evidence suggests that certain antecedents of life satisfaction, such as religiosity or the quality of relationships, have been found to be correlated with both increased life satisfaction and health-beneficial social support environments (Kringelbach & Berridge, 2010). In this way, the experience of life satisfaction has been found to be associated with participation in social and community activities (Kringelbach & Berridge, 2010). This would in turn indicate that the experience of being and wanting to be more satisfied with life may encourage an individual to further seek out psychosocially supportive resources that may be beneficial to health in the form of increased social support for health beneficial behaviour as well as provide social support in the event of illness or trauma (Kringelbach & Berridge, 2010). As such, the evidence appears to imply that life satisfaction is correlated with the type of prosocial behaviour that encourages health beneficial behaviour and enhances social support in the event of illness or trauma, thus hastening recovery.

The type of prosocial behaviour that is associated with high levels of life satisfaction has been indicated to be correlated with activity in the ventro-medial prefrontal cortex (vmPFC) in an area that has been suggested to be associated with social emotions such as empathy or guilt (Feder, Nestler, & Charney, 2009). Studies have suggested that the mirror neuron system in the brain may play a part in this prosocial behaviour, by helping individuals understand others emotions and behaviour (Feder et al., 2009). Furthermore, increased amount of oxytocin has been indicated to be associated in this form of prosocial behaviour (Feder et al., 2009). Oxytocin has been indicated to be a factor on the psychosocial aspect of both life satisfaction by enhancing the value of social stimuli and reducing fear responses by reducing amygdala activation (Feder et al., 2009). In summary, the evidence would appear to
suggest that life satisfaction is correlated with and tentatively appears to encourage prosocial
that in turn indirectly benefits health.

**Bottom-Up Effect Processes**

The Bottom-Up Effect assumes that the primary effect is from health to life satisfaction and that health is considered to be an antecedent to life satisfaction (Gana et al., 2013). Evidence for a bottom-up relationship was found in a longitudinal study that examined the relationship between life satisfaction and health in a sample of older adults, suggesting that health influences life satisfaction in significant ways while there was no significant effect from life satisfaction to health (Gana et al., 2013), implying the relationship between health and life satisfaction may be more of a bottom-up effect. The processes that have thus far been most implicated in this is self-perceived health (Gana et al., 2013) and optimal metastability in the brain (Kringelbach & Berridge, 2010).

**Positive self-perceived health.** A longitudinal study of 899 older adults aged from 64 to 97 years over a period of 8 years that examined the roles of cross-lagged and simultaneous effects in the relationship between life satisfaction and health through measurement of life satisfaction with the SWLS and by monitoring health through self-reported symptoms and self-assessed subjective health (Gana et al., 2013). The results of this study indicated that the cross-lagged paths from health to life satisfaction were significant ($r = -.15$ to $r = -.18$), while none of the paths from life satisfaction to health were ($r = -.03$) (Gana et al., 2013). According to the conclusions of the study, this would indicate that in their sample of older adults, physical health was an antecedent to life satisfaction and as such the influence from health to life satisfaction was not insignificant (Gana et al., 2013). The results further indicated that in their sample, life satisfaction had no independent effect on mortality (Gana et al., 2013). The study further implicates health status as a strong predictor of both marital happiness and life satisfaction (Gana et al., 2013). In summary, the evidence appears to
suggest that self-perceived health is a major factor in the cognitive process that assesses a person’s level of life satisfaction and that life satisfaction as a construct had no direct effect on health or mortality.

**Optimal metastability in the brain.** Theoretical evidence suggests that life satisfaction is correlated with optimal metastability in the brain, that is to say that the various pathways in the brain are functioning optimally in relation to each other (Kringelbach & Berridge, 2010). Further evidence indicates that healthy functioning of the default mode network is closely associated with representations of self in addition to being implied to be crucial in connecting hedonic and eudaimonic well-being (Kringelbach & Berridge, 2017). This would appear to suggest that the optimal functioning of the cognitive process that forms an individual’s level is closely related to the physical healthy functioning of the brain as an organ. In summary, the evidence implies that life satisfaction is in part a result of the physical health of the brain.

**Bidirectional Effect Processes**

The Bidirectional Effect assumes that life satisfaction and health have bidirectional effects on each other, with no primary direction of effect. This effect is based on the top-down and bottom-up model from SWB literature that suggests that life satisfaction is both a cause and a result of health (Feist et al., 1995). This suggestion is the result of an experiment on 160 postgraduate university students that examined the role of various latent factors in the formation of SWB (Feist et al., 1995). As such, the Bidirectional Effect suggests the possibility of a positive feedback of top-down and bottom-up processes acting in concert with each other. Furthermore, the process of resilience has been indicated to possess a process that has an independent bidirectional effect on both health and life satisfaction (Kong, Wang, et al., 2015).
Psychological and physiological resilience. Resilience is the psychological and physical ability to thrive when faced with risk and adversity (Kong, Wang, et al., 2015) and the ability to adaptively react to both stress and stressors in the environment (Schwerdtfeger et al., 2017). Resilience has been closely associated with both high levels of life satisfaction (Kong, Wang, et al., 2015) and physical health, in particular faster recovery from illness and injury and psychological conditions that also affect physical health such as depression (Wu et al., 2013). Furthermore, resilient individuals have been observed to possess a stronger analgesic reaction to pain and as such experience less intense pain (Peciña et al., 2013).

An fMRI study of 172 university students found that resilience was negatively correlated with regional homogeneity (ReHo) in the insula and the right dACC and rACC (Kong, Wang, et al., 2015). Reduced activation in the insula has been found to be associated with greater non-reactivity of inner experience, something that has been found to be a key component of mindfulness that may protect against depression and reduce vulnerability to depression (Wu et al., 2013). This also provides implication on the neural process behind resilient behaviour (Wu et al., 2013). This evidence would suggest that resilient individuals are resilient due to the nature of their inner experience that minimizes the impact external stressors have on their inner experience.

Other studies indicate that enhanced functioning of the brain’s reward circuitry contributes to resilience, particularly to physical stress and trauma (Wu et al., 2013). A key reward circuit in this regard is the mesolimbic dopamine pathway that transmits dopamine signals from the ventral and segmental area of the mid-brain to the limbic system, in particular the nucleus accumbens and other related brain regions such as the amygdala, hippocampus and mPFC (Wu et al., 2013). This pathway is indicated to be associated with behavioural responses to rewards such as food or sex (Wu et al., 2013). This would appear to
suggest that functioning of the reward circuit enables resilient individuals to better reinforce adaptive behaviour to both stress and trauma.

Resilience has also been found to be associated with the brain’s fear circuitry, the amygdala, the hippocampus and the vmPFC (Feder et al., 2009). It is theorized that when this circuitry functions well, it prevents over-generalizing the reactions to specific stimuli through inhibition of amygdala response by the mPFC in stressful situations (Feder et al., 2009). This would indicate that resilience improves both life satisfaction and health by acting a protective factor against mentally overgeneralizing response to stressful and frightening situations and as such, resilience further promotes adaptive behaviour in relation to specific events in contrast with overgeneralized responses.

Further study of 75 participants indicated that life satisfaction could be associated with beneficial hemodynamic reactivity, meaning that individuals who are more satisfied with their lives can cope more adaptively physically with stress and as such possess greater levels of resilience (Schwerdtfeger et al., 2017). This same study also indicated that by contrast, lower levels of life satisfaction or even dissatisfaction were associated with less adaptive hemodynamic responses to stress (Schwerdtfeger et al., 2017). This would appear to indicate that life satisfaction at least partially is able to effect health through promoting resilient physical response to stress.

In summary, resilience is a complex process that appears to be both a factor and a result of both life satisfaction and health that appears to primarily act as a protective process that promotes adaptive psychological and physical responses to stress.

**Discussion**

The aim of this thesis was to examine the bidirectional relationship between life satisfaction and physical health from a neural perspective, with a specific focus on what
processes may play a role in this relationship and what evidence if any can be provided for a primary direction and active processes in this relationship. Therefore, for the purpose of clarity, this thesis will discuss this relationship in two sections – first directionality, then by processes implied to be involved.

The consensus within the literature appears to be that life satisfaction is consistently correlated with higher self-reported health (Ngamaba et al., 2017) and by contrast, life dissatisfaction, especially if it has been allowed to become chronic, is consistently correlated with lower self-reported health and higher mortality (Koivumaa-Honkanen et al., 2004). This correlation has been observed in both individual studies and review studies with large experimental populations (Diener & Chan, 2011). As such, the argument can be made that there is convincing evidence for a relationship between life satisfaction and health, but the exact nature and directionality of this relationship as well as what biological processes are active within this relationship remains unclear. Therefore, to better establish an understanding of how this relationship functions to provide scientific evidence for the processes at hand, it becomes pertinent to further study how life satisfaction, a cognitive experiential state in the brain, can affect physical health and vice versa.

Life satisfaction is an assessment of how satisfied an individual is with his or her life in total. (Diener, 1994). Though closely associated with positive affect, this evaluation is cognitive in nature. While it may act as precursor to further hedonic positive affect, this state of life satisfaction is not a purely hedonic state, but rather appears to combine elements of both hedonic and eudaimonic well-being, particularly in the more collectivistic culture of Eastern Asia (Diener et al., 2003). As such, the argument can be made the life satisfaction is a long-term state of well-being that is based on a multitude of factors, and despite continuing variations in the individual’s life circumstances remains fairly stable. Therefore, the further argument can be made that the stability of life satisfaction must be at least partially based on
some other variables than the sometimes daily varying life circumstances. In fact, evidence has been provided that indicates that environmental and demographic factors form roughly 8-15% of life satisfaction (Lent, 2004), while culture affects roughly 12% (Diener et al., 2003), and genetic predisposition affects 80% of life satisfaction (Lent, 2004).

Based on this evidence, the argument can be made that life satisfaction is at least partially a trait-like construct that, based on the available evidence appears to have a strong genetic component. This is of particular note in the case of individuals who may be genetically predisposed towards satisfaction and as such may greatly benefit from the relationship between life satisfaction and health. The opposite argument can be made for the individuals whom are genetically predisposed towards life dissatisfaction, as in these cases life dissatisfaction has been correlated with more health adverse behaviour and mortality (Koivumaa-Honkanen et al., 2000). Therefore, to further examine why certain individuals appear to glean the benefits of a positive relationship and others appear to suffer from the effects of a negative relationship, it becomes more conducive to closer examine the exact directionality and processes involved in this relationship.

**Directionality Examined**

The question of directionality within this relationship can be stated to be similar to the question of directionality between life circumstances and SWB within the literature that has debated the relationship based on two theoretical models – the Top-Down model and the Bottom-Up model (Leonardi et al., 2005). Within the realm of SWB as a whole, of which life satisfaction forms a part, there have been indications that suggests that subjective well-being is both a factor and a consequence of health (Feist et al., 1995). However, this evidence appears to apply only to SWB as a whole, which in turn is a larger construct that includes life satisfaction as merely one part. This evidence raises the possibility that the relationship between life satisfaction and health may be complicated in nature with possibly overlapping
directionality. However the primary finding of this thesis has been that most studies that have examined the directionality in this relationship have been consistently cautious in discussing causality even tentatively and have preferred to discuss life satisfaction as a reliable predictor of future self-perceived health (de Waure et al., 2015), or on the opposite side of the directionality debate, health as a predictor future life satisfaction (Gana et al., 2013). Therefore this thesis will also only draw tentative conclusions or arguments with regards to directionality.

The majority of the studies that have examined the directionality within the relationship appear to support the existence of the Top-Down Effect that suggests that life satisfaction may directly impact health, particularly if these studies are made from the perspective of positive or coaching psychology (Lyubomirsky et al., 2005). However, on closer examination, it becomes apparent that the vast majority of the studies that have provided evidence for a Top-Down Effect have had test populations of primarily young adults or adults under the retirement age (Kong, Hu, et al., 2015; Ngamaba et al., 2017; Schwerdtfeger et al., 2017). In contrast, the few studies that have examined the relationship in an older adult over the retirement age in general population have displayed evidence for a Bottom-Up Effect (Gana et al., 2013). This evidence may indicate that the directionality may be dynamic in that the primary directionality within the relationship may change during an individual’s lifetime, depending on environmental factors or the person’s age due to the effects of aging on the brain. This argument for a dynamic directionality may further be supported by evidence that cognitive control in older and younger adults function differently (Amer, Campbell, & Hasher, 2016).

Other studies indicate that self-reported physical ailments, as well as loneliness and the feeling of helplessness in particularly may play a significant role in formation of life satisfaction in older adults (Kajonius & Kazemi, 2016). This would further indicate that the
relationship between health and life satisfaction, especially in older adults, may be further attenuated by how much control the individual experiences over how his or her health is cared for. However, other arguments can be made based on the fact that life satisfaction most often appears to peak around the age of 65 (Mroczek & Spiro, 2005). As this age appears to coincide with the time when the Top-Down relationship changes into a Bottom-Up relationship, based on the available evidence, it may be that as an individual ages, the effects of life satisfaction on health become less salient and as a result the impact of life satisfaction on health is lessened. While this may appear to be a simple conclusion, it is confounded by the fact that older adults that maintain their social contacts and stay physically active often report higher levels of both health and life satisfaction (Gana et al., 2013; Mroczek & Spiro, 2005), therefore indicating that efforts to maintain either life satisfaction or health are still effective on both, even if the impact of life satisfaction on health is lessened.

Furthermore, evidence has indicated that the intensity and impact of this relationship also varies due to the personal traits of the individual. Life satisfaction is correlated with extroversion and negatively correlated with neuroticism (Diener et al., 2003). The evidence would appear to indicate that individuals who are more satisfied with life and are more prone to experiencing positive affect and are less prone to ruminating over their life circumstances are the most prone to receive a beneficial health effect from the relationship (Diener & Chan, 2011; Lyubomirsky et al., 2005). As such, from a neural perspective, the argument can be made that as life satisfaction, self-esteem and extroversion is correlated with grey matter volume in the areas of the brain that are responsible for cognitive presentations of self (Kong et al., 2014) as well as the intensity of inner experience (Wu et al., 2013). As such that being satisfied with life is correlated with a greater non-reactivity and lesser intensity of the inner experience in connection to experienced negative states. This in turn provides evidence to support the claim that the directionality of the relationship may at least partially be attenuated.
by personality traits and their neural correlates. As such, the argument can be made that while stable long-term personality traits may support and enhance the relationship between life satisfaction and health, changes to these traits or their neural correlates as the result of trauma (Wu et al., 2013) or ageing (Amer et al., 2016) may alter the intensity or directionality in the relationship.

Therefore, with regards to directionality the tentative conclusion remains that the directionality may well be a dynamic relationship that changes in both directionality and intensity during an individual’s lifetime. This may be partially due to the physical effects that aging has on the brain as an organ.

**Processes Examined**

While the exact directionality and nature of the relationship between life satisfaction and health remains unclear, it would appear that at least tentative indications for what processes are active in this relationship can be provided. The primary findings of this thesis, with regards to processes, are that in the case of Top-Down Effects, the effects appear to be primarily based on the fact that life satisfaction is correlated with grey matter volume in the areas of the brain such as dACG and rIPFC that are correlated with cognitive controls and the reinforcement of learning (Takeuchi et al., 2014). This may provide further support to the assumption that life satisfaction acts as a signal that reinforces the individual’s health beneficial behaviour and discourages health adverse behaviour. As such, it may be that life satisfaction, through inner experience, teaches an individual to accept those behaviours that are beneficial to the individual’s health and discard the health adverse behaviours. This is further supported by evidence that suggests that life satisfaction as a state is more closely associated with the liking state within the hedonic pleasure network in the brain than the wanting state (Kringelbach & Berridge, 2017). However, it should be noted that this process
can be thwarted by other hedonic signals, such as short-term pleasurable liking of a health adverse behaviour, such as enjoying unhealthy food or smoking (Baumann et al., 2017).

Other findings in the support of Top-Down Effects are supported by the evidence that suggests that life satisfaction is negatively correlated with areas of brain that are traditionally active when pain is subjectively experienced (Takeuchi et al., 2014). This indication, coupled with the greater non-reactivity of inner experience (Wu et al., 2013), provides evidence to suggest that a further Top-Down Effect is a high degree of life satisfaction acting as a protective measure against the subjective feeling of pain or the negative feelings associated with hardship in daily life. This argument has been further supported by study of Special Forces soldiers during extreme training that has indicated the most adaptive individuals in training have possessed personality traits commonly associated and correlated with high life satisfaction (Simeon et al., 2007).

In regards to Bidirectional Effect, the primary finding of this thesis has been that resilience, associated with both high levels of life satisfaction (Kong, Wang, et al., 2015) and high self-rated health (Simeon et al., 2007) has been indicated to be a central process. Resilience is frequently closely associated with the analgesic and stress-tolerant protective effects of high life satisfaction (Wu et al., 2013) and even on a physical level resilience appears to foster a more adaptive response to stress and daily hardship (Schwerdtfeger et al., 2017). From a neural perspective, resilience is negatively correlated with regional homogeneity in the insula, the right dACC and the right rACC, thus indicating that the Salience Network that affects how salient stimuli is in the subjective conscious experience. Resilience has been also found to be neurally correlated with optimal functioning of the areas of the brain associated with fear, such as the amygdala, hippocampus and vmPFC (Feder et al., 2009) as well as the reward network of the brain (Wu et al., 2013). Therefore, the evidence would appear to indicate that resilience is both a factor and a consequence of
both life satisfaction and health by lessening the intensity of inner subjective experience of adverse or noxious stimuli, while encouraging an adaptive and not overly generalized reaction to the same. In practice, this would appear to indicate that high levels of resilience may be fostered by quality healthcare in connection with interventions specifically tailored to improve resilience. This in turn may lead to higher life satisfaction.

The primary finding of this thesis with regards to Bottom-Up Effect is that the effect of health on life satisfaction is partially based on the psychological impact of having high self-rated health, especially in the case of older adult individuals (Gana et al., 2013) and that other effects of health on life satisfaction may be the physical health of the brain enabling the experience of life satisfaction (Kringelbach & Berridge, 2017). This evidence seems to suggest that at least a certain baseline of health especially within the neural networks of the brain strongly affects life satisfaction as low levels of life satisfaction are commonly associated with people with depression, PTSD or brain lesions in the neural areas associated with life satisfaction (Han & Nestler, 2017). As such, the suggestion would appear to be that while health may have a stronger impact on life satisfaction in certain populations than others, especially along the age-axis that a certain minimum level of health, is required for life satisfaction particularly with regards to the physical health of the brain.

Practical Implications

The practical implications of the directionality and tentative processes of the relationship between life satisfaction appears to primarily support the argument that treating individuals in a holistically complete manner that combines physical healthcare with psychological interventions could according to the available evidence provide an effect that is greater than the sum of its individual treatments and interventions. This is of particular note in preventative healthcare where patients frequently respond negatively with considerable resistance to suggestions to change their behaviour in more health beneficial ways (Baumann
et al., 2017). The observation has been made that if the healthcare practitioner, especially in the realm of preventative healthcare, focuses more on creating a sense of partnership that enhances inner motivation in the client then the client is more like to make permanently beneficial changes to behaviour (Baumann et al., 2017; Frisch, 2013). As a consequence, the argument can be made that if traditional healthcare would be combined with more of a psychological coaching approach that combines elements of cognitive behaviour therapy and appropriate therapeutic approach then both the physical and mental well-being of individuals could be improved (Frisch, 2013).

Resilience and its implication can be further considered to be of particular interest to practical implications. As a central process that has been implicated in all three directionalities of effect, focusing on resilience interventions provides a practical opportunity to examine the role and effect of this process in the relationship. Furthermore, as the potential benefits of increased resilience include both increased life satisfaction and improved health, in addition to other benefits such as fostering more adaptive behaviour and perhaps even having an inoculatory effect against stress (Simeon et al., 2007). As such, the practical implication appears to be that focusing on resilience in the context of stress-related preventative or other healthcare may be especially beneficial.

Furthermore, as resilience is indicated to be fostered by positive relationships and secure attachment during childhood (Simeon et al., 2007; Wu et al., 2013). Therefore the practical implications becomes that if the society provides the possibility for parents to foster resilience in their children from an early age that the following benefits in both health and life satisfaction – and by extension happiness - both to the people as individuals and to society as a whole could be noticeable. Consequently, such a holistic approach in promoting factors that promote health even later in life would provide further argumentation to why political decisions should be based on Bentham’s Greatest Happiness Principle (Bentham, 1823).
While this argument could be made from purely humane grounds, other evidence can be provided to support the argument from an economical point of view. If resilience and other beneficial psychological and biological processes are fostered from an early age this would lead to not only improved health in the general population, but also in economical savings in public healthcare, particularly in relation to preventable diseases or diseases that are at least partially the result of willing health adverse behaviour.

**Limitations and Future Research**

As a review study of the available scientific literature, this thesis is considerably limited in drawing conclusions in regards to even tentative causality and subsequent practical implications. As such, the results of this thesis should be only used as tentative results that provide implications and ideas for future areas of research. Furthermore, most of the studies examined in this thesis have been relatively homogenous in their test populations and such have been unable to provide scientific data on the effects of various factors on the relationship between life satisfaction and health.

An example of this limitation is the influence of age on this relationship. Studies with younger populations have consistently identified a correlation between life satisfaction and health or have been able to provide evidence that life satisfaction can be used as a stable predictor of future good or poor health (Al-windi, 2005). However, studies that have examined older populations have found evidence for the contrasting viewpoint that implies that self-reported health can be used as a reliable predictor of future life satisfaction (Gana et al., 2013). As such, the ability of this thesis to provide conclusive evidence for the effect of age on the relationship has been limited and more research into this field is necessary.

A similar limitation can be stated to exist with regards to gender and its effects on this relationship. While some of the available data suggests that gender, particularly with regards to neuroticism, has an effect in the formation of life satisfaction (Feist et al., 1995) and on
reported amount of somatic symptoms in association with reported life satisfaction (de Waure et al., 2015). This is particularly confounded by the factor that female participants, while rated for higher neuroticism, also report higher satisfaction (Feist et al., 1995). This is considered to be in contrast with the rest of the literature that consistently provides evidence for the negative correlation between neuroticism and life satisfaction. Furthermore, female participants, while rating their life satisfaction as higher, also report higher amount of somatic symptoms (de Waure et al., 2015). This may be due to biological differences, or based on social norms that hinder one gender in reporting their symptoms and encourage the other to do so. As such, to explore the role of gender and associated societal desirability in both life satisfaction in general and in particular in the relationship between life satisfaction and health, further research into this field is required.

Most of the studies examined for this thesis have had relatively homogenous experimental populations with regards to age, social rank, geographic location or cultural influences. As such, larger longitudinal studies with more heterogeneous and more cross-lagged analysis of various factors may provide clarity in the role culture and demographic have on the relationship between life satisfaction and health.

Applied research in situ settings into the effectiveness of various interventions, in particular psychological resilience interventions further may provide clarity on the exact role that resilience has in the relationship. This form of research would also provide useful information on how to further develop interventions that may be used to either improve both health and life satisfaction or to prevent more adverse health episodes as the result of maladaptive response to stress or other health adverse factors.

Furthermore, as the evidence appears to indicate that both baseline health and life satisfaction may have a strong basis in genetic predisposition (Kajonius & Carlander, 2017), future research into gene therapy may be beneficial to further examine the role of genetics in
both health and life satisfaction. However, due to the ethical implications of such methods, such research ought to be carefully considered for both practical and societal implications.

**Conclusion**

In conclusion, the literature seems to imply that positive life satisfaction is correlated with physical health, adaptive health behaviour and longevity. In contrast, life dissatisfaction is correlated with adverse health episodes and mortality. These correlations appear to be fairly robust in nature though the direction of this relationship appears to be unclear based on the available evidence. However, in practice this implies that if satisfaction with life can be improved or dissatisfaction can avoided altogether that people’s health can also be improved as a result and, vice versa, if quality healthcare can be provided to larger population that the overall life satisfaction in society can be improved as well.

From a neuroscientific perspective, the evidence also appears to indicate that at least a certain base level of neural health and function is necessary to be able to experience life satisfaction. Furthermore, the results indicate that optimal functioning of the brain’s networks in relation to each other may promote life satisfaction.

Resilience is indicated by theoretical and observed neural evidence to play an important role in facilitating the relationship between health and life satisfaction. As such, interventions to improve resilience may provide a long-term indirect benefit to both health and life satisfaction. Further evidence appears to suggest that genetic predisposition has a significant effect on both life satisfaction and health.

With regards to directionality, the evidence appears to indicate that directionality in the relationship between life satisfaction appears to be dynamic. More particularly, the findings appear to suggest that aging may be a factor that affects directionality. In summary, the question of are we happy because we are healthy, or healthy because we are happy still
remains and more research is in order if any directionality and the factors that affect it are to be firmly established.
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