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If, Why, and When Subjective Well-Being Influences Health, and Future Needed Research

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We review evidence on whether subjective well-being (SWB) can influence health, why it might do so, and what we know about the conditions where this is more or less likely to occur. This review also explores how various methodological approaches inform the study of the connections between subjective well-being and health and longevity outcomes. Our review of this growing literature indicates areas where data are substantial and where much more research is needed. We conclude that SWB *can* sometimes influence health, and review a number of reasons why it does so. A key open question is when it does and does not do so—in terms of populations likely to be affected, types of SWB that are most influential (including which might be harmful), and types of health and illnesses that are most likely to be affected. We also describe additional types of research that are now much needed in this burgeoning area of interest, for example, cross-cultural studies, animal research, and experimental interventions designed to raise long-term SWB and assess the effects on physical health. This research area is characterised both by potentially extremely important findings, and also by pivotal research issues and questions.

Keywords: happiness, health, positive affect, subjective well-being

INTRODUCTION

Literature reviews and meta-analyses of the scientific literature have generally concluded that subjective well-being (SWB) can be beneficial to health and longevity. Our aim is to give a broad overview of the research and reviews in this

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area, including the mediators and moderators that help explain the effects of SWB on health, as well as the various research methods that have been used. Our review is designed to help scientists see more clearly where important research is needed in this field.

Subjective Well-Being

Many different terms are used in the psychology literature to describe well-being. Readers are referred to Diener, Oishi, and Lucas (2017) for more extensive detailed coverage of this topic. “Psychological well-being” is the broadest and most all-inclusive term. It includes “Subjective well-being”, which is how individuals evaluate or appraise their own lives. To what degree does a person evaluate her or his life and current situation as good and desirable versus undesirable and negative? These evaluations can be either in terms of cognitive reflections, representing reflective appraisals of life and domains of life such as work, or can be in terms of affect. The person’s affect includes feelings of various types, including emotions and moods. Positive affect includes the various feelings people experience when things seem to be going well, and negative affect is the experience that things are not going well. Positive affect includes both momentary emotions such as enjoyment, and more chronic long-term moods such as contentment. Negative affect includes momentary or “state” emotions such as feelings of anger, sadness, stress, and worry, and also longer-lasting moods such as depression that occurs over time. Another form of SWB is “optimism”, which often correlates with positive affect, but includes positive expectations about the future.

Often a distinction is made between reflective forms of SWB and the experience of momentary SWB, although the two are correlated. Another form of psychological well-being that has been assessed in this area is “eudaimonic” well-being, which includes variables such as meaning and purpose in life, supportive social relationships, and feelings of mastery. There is an ongoing debate about the distinctiveness of various types of SWB, but this topic is beyond the scope of the current review. In this review we examine the relation of different forms of SWB, such as life satisfaction, positive affect, optimism, and low negative affect, with health and longevity. As will be seen, there is still much to be learned about the overlapping versus distinct influences of the types of SWB on health.

Our review is focused on the effects of somewhat enduring stable levels of SWB rather than on the effects of momentary moods. However, the effects of moods can be quite informative because they often indicate how SWB exerts its effects. We do not focus on mental health in this review, as it is covered in other reviews. However, there is substantial overlap between many of the mental health measures that have been used and what we define as negative affect.

Purposes of this Review

In light of the fact that a number of reviews and meta-analyses of this area have been published, there are several purposes of the current review:

1. To examine recent evidence, as well as other types of evidence such as research on SWB and genetic markers, and SWB effects in animal health that have not been adequately reviewed in the health context.
2. To review how evidence drawn from different types of research methodologies each adds to our understanding of the pathways by which SWB can influence health.
3. To use our multi-method review to show where the important gaps are in the literature and the biggest areas in need of more research. By comprehending what each method adds, we can determine what types of information and studies are missing from the current literature.
4. To review the literature within the framework of complex system dynamics, in which the key variables are both influenced by and influence other key variables. In this framework it is essential to search for the mediators of the SWB and health association, as well as the moderators that make the effects stronger or weaker. Furthermore, it is essential to understand statistical controls in conceptual terms, and not merely as the control of potentially confounding variables. In general a more sophisticated approach to statistical control of possible confounds could be helpful in this field. A dynamic systems approach alerts us to the fact that some variables that are treated as confounds in this literature can be causes or effects of SWB, and therefore it is risky to automatically treat them as confounds.

The Value of Multiple Research Methods

Each type of research method has strengths compared to the other methods, and therefore conclusions drawn from each method are useful. More complete understanding of the dynamic system connecting SWB to health can be gained if we consider, in addition to the knowledge gained from correlational, experimental, and longitudinal designs, nonhuman animal studies, as well as factors such as mediation, moderation, causal modeling, and short- versus long-term mood effects. Some laboratories rely exclusively on one method, although a more catholic approach to methods might aid in the understanding of the issues they are addressing. Below we list some of the strengths and limitations of each of the various methodological approaches.

A. Correlational methods are relatively quick and inexpensive compared to most other methods. Simple cross-sectional correlations between SWB and health can be used to examine a spectrum of associations across large and diverse subject samples. Such correlations can reveal the generality of the associations, and statistical controls of additional variables can help understand the

linkages in the system. Correlational methods allow us to discover links in the SWB and health system in a cost-effective and methodologically simple manner that can focus and give direction to more intensive later studies.

B. Experimental studies can reveal causal connections in a strong way that is usually not available when using the other methods. However, these methods often only tell us whether an association can occur, but not whether it is a major causal connection in the natural world. Furthermore, experiments frequently do not make clear the context or border conditions that must be present for the connection to occur. Furthermore, often it appears that the manipulated variable has an effect, but we do not know why some participants are affected and others are not. We also do not know about the generalisability of the findings to other cultures, populations, situations, and personalities. It is possible to discover these things through repeated experiments across many settings, samples, and cultures, but this is often not the most efficient initial step.

Scientists who rely heavily on experimentation sometimes criticise other methods because in using those methods one can never control all possible confounding variables, although one can frequently control the most obvious and seemingly important ones. However, a parallel problem with experimentation is that the scientist can usually not be certain of all that is being changed by the intervention, and what the active component is with certainty. For instance, interventions to raise well-being can alter factors such as social relationships and meaning and purpose in participants' lives, both of which might be responsible for health effects independently of SWB.

Health research experimentation, in particular, comes with its own unique set of limitations. Given the goal to not harm research participants, there are few illnesses that we can experimentally give to a participant (see Cohen, Alper, Doyle, Treanor, & Turner, 2006, on the common cold and influenza for exceptions), and, similarly, we cannot alter behaviors in a health damaging manner (e.g. inducing smoking). Furthermore, because of the large stakes of studies experimenting on important health outcomes (e.g. disease survival or longevity), it is growing more difficult to maintain adequate control groups and hold off providing participants with treatments and manipulations known to be effective in improving wellness outcomes. Because medical researchers work with similar constraints, they have long embraced the importance of non-experimental research as useful, functional, and essential. Another pragmatic limitation to long-term experimentation is that it is difficult and very costly to change people's long-term levels of SWB in a way that can influence future disease and mortality outcomes, or reverse the effects that have already occurred.

A final issue should be mentioned in terms of experimentation, and that is that philosophers, going back to Aristotle, differentiate several types of causality—it is not a single thing. The type of causality that is studied with experimentation is concerned with whether actions we take change the likelihood of an outcome. The experimental methods as typically used do not tell us whether the thing we

manipulate is necessary or sufficient for the outcome, and often do not reveal the mediators, how the events unfold over time, or the moderator and context conditions required for the outcome to occur.

C. Prospective longitudinal studies can tell us whether one variable predicts another variable later in time, and whether changes in the first variable are followed by changes in the second. These studies complement experiments. Although not possessing the same internal validity in terms of causal inferences, they have the strength of being able to determine a sequence of events in the natural world. Possible confounding variables can be assessed and analyzed. Furthermore, longitudinal methods can reveal the unfolding of dynamic systems across time, as well as patterns over many years and even decades. However, it is often argued that causality cannot be determined with as much rigor as in experiments because one cannot be certain that all potentially confounding variables have been controlled.

D. Mediators, moderators, and causal modeling analyses seek to determine the intervening processes that explain causal connections, as well as the broader dynamic system that must be in place for it to occur. Mediation analyses seek to explain why SWB influences health by examining the behavioral and physiological outcomes of SWB that might in turn influence health. Moderator analyses and causal modeling seek to determine the other contextual variables that must be in place for the causal sequence to occur, or which make it a stronger or weaker connection. In causal modeling we can also seek to understand the bidirectional nature of causal influences.

To understand behavioral systems we must gain insight into the proximal versus distal influences on an outcome, and understand that these influences might be related not only separately to the outcome, but also directly to each other. It is also essential to differentiate possible third-variable explanations of the SWB and health association from factors that might cause or result from SWB and be an important aspect of understanding the effects of SWB.

E. Animal research is rare in the SWB and health area, but is becoming more commonplace. It has the advantage that some of the confounding variables that are troublesome for human research can be controlled in animal research, such as differences in nutrition and the environment. Furthermore, experiments are sometimes ethically permissible in animal research that cannot be conducted with humans, allowing for stronger inferences to be made. Finally, animal research helps us generalise the findings found in humans.

CONCLUSIONS ON THE VALUE OF MULTIPLE METHODS

The type of methodology used by researchers should be chosen based on the questions being asked and goals of the research, rather than on a continuum of better and worse methods. One's initial research question, hypotheses, and goals of the inquiry point to the best method for a particular study. In this review we

assume that each method is sometimes the best tool for answering specific questions most efficiently. Instead of awarding gold-standard status invariably to experimentation, we suggest that the gold standard should be the method that best fits the questions being addressed. While experimentation offers perhaps the most rigor in terms of control, correlational studies are often a more efficient way to answer initial inquiries, and longitudinal studies can answer questions that are very difficult to address with experimentation alone. Furthermore, the type of causal knowledge provided by experimentation needs to be supplemented with information on mediators, moderators, and considerations of the entire dynamic system that is involved in health.

We suggest that a broad approach is needed—Scientific Understanding Through Multiple Methodologies (SUMM). In this approach we recognise that the phenomena in the field of human behavior and health occur in complex and dynamic systems, and that the best way to gain a fuller understanding of these systems is by using different methods for different aspects of the inquiry. One can ask whether fields that have become too enamored with experimentation have produced laboratory knowledge without knowing how much it explains phenomena outside of the laboratory. We believe that SUMM can offer the scaffolding for using different methodological approaches to gain an integrated explanation of phenomena occurring in complex systems.

PREVIOUS REVIEWS

In reviewing the studies we cite meta-analyses of that area where they are available, to ensure a more comprehensive and systematic review of each issue. Tables 1 through 9 of this paper, and the supporting references, can be found in the Appendix. Because meta-analyses, with their systematic location of publications and their objective method of summarising results, are methodologically often stronger than simple literary reviews, in Table 1 first are listed the meta-analyses of various areas that have been conducted, and then traditional literature reviews. It can be seen that various types of SWB have been found to be associated with longevity and various health outcomes. The results occur across the meta-analyses and literary reviews, although they are not found in all studies.

In the following sections of this paper we describe in the Appendix findings from a number of individual studies to give readers a clear idea of the research that has been conducted. Our aim is to give readers a broad overview of the various methods and types of evidence that are available, with the goal of describing the most needed research at this time. What we hope to achieve in this article is to give a broad view of all the types of evidence that now exist, both in terms of methodologies and also in terms of mediation and moderation. By taking a broad approach, we are able to view the effects of various forms of SWB, and how the outcomes of various methods do or do not converge. We hope to indicate where more rigorous, large-scale, and probing research is needed. One area we cover is

desirable ways to conduct statistical analyses in this field, and especially in the area of controlling possible confounding variables. Our suggestions are applicable to new research, but should also apply to re-analyses of existing data sets.

CROSS-SECTIONAL CORRELATIONAL STUDIES

In Table 2 we present a few examples of cross-sectional correlational studies. It can be seen in the table that the correlational studies are quite diverse. Associations have been found across nations between SWB and general health, as well as SWB and specific health and physiological variables. Immune, cardiovascular, and endocrine measures have all been found to be associated with several forms of SWB. The examples of studies in Table 2 make evident that in correlational studies, even when statistical controls are applied and the observed association is clear, researchers are unable to determine the direction of the relationship. This bidirectional uncertainty limits the causal inferences that researchers are able to claim.

The strength of the correlational methodology is that it can be used to discover initial associations between variables gleaned from large-scale, representative samples that can often be gathered quickly and easily, or acquired from secondary sources. Efficiency, practicality, data collection and analysis on a global scale are a few of the major advantages of this method. Furthermore, researchers are usually able to gather relevant data without crossing ethical boundaries.

LONGITUDINAL STUDIES

Using longitudinal methods allows researchers to determine not only a temporal ordering of events—whether SWB levels predict future health and mortality—but also whether a change in SWB over time predicts a change in health. Furthermore, these methods allow us to examine the natural unfolding of developmental variables over long periods of time. Because many health conditions occur over many years or even decades, it is virtually impossible to examine their causes using only experimental methods. Furthermore, whereas experiments ask whether an association *can* occur, longitudinal designs observe this association over time in the natural world—whether the association *does* occur. Longitudinal methods allow us to view the effects of SWB in natural circumstances in interplay with other conditions that influence health. In Table 3 we present examples of studies of SWB and health that have used longitudinal designs. The studies generally show that various types of SWB are associated with greater longevity and superior health outcomes over time. However, we will see later that these desirable outcomes are not found for all groups of people across all studies.

Longitudinal studies provide evidence that SWB can influence both health and mortality, but with the caveat that other uncontrolled factors might be causing the observed association. Even when controlling for a variety of possible third variables (e.g. genetics, income), SWB frequently predicts future health.

Yet, even with statistical controls longitudinal studies do not with certainty rule out third-variable explanations of the findings. There might always be other unobserved variables that are responsible for the association. Thus, we need additional methods to fully resolve the third-variable problem and firmly establish directionality.

Longitudinal studies are often costly, have problems with attrition of participants, and the most appropriate measures may change as time progresses. Furthermore, many of the meta-analyses find evidence of publication bias. One possible solution to this problem includes the examination of dissertations where the demand for significant results is lower. Furthermore, fail-safe studies suggest that the existing findings are probably valid and not simply due to chance. Most of the studies confirmed predictions even when sociodemographic variables were controlled.

EXPERIMENTS DESIGNED TO RAISE LONG-TERM SWB AND DETERMINE THE EFFECTS ON HEALTH

Long-term experiments on SWB and health or longevity include randomised assignment of participants to conditions and the inclusion of control groups. This method is implemented to examine the effectiveness of psychological interventions to benefit health outcomes. These studies have the strength of occurring in the natural world, as well as the control and greater certainty that comes from randomised controlled trials. Lyubomirsky, King, and Diener (2005) reviewed experimental evidence for the influence of SWB on health. In Table 4 are listed experimental trials designed to raise long-term SWB and measure changes in health and health behaviors, with over half being published since the Lyubomirsky et al. review.

It can be seen in Table 4 that a number of randomised controlled trials have now been conducted in which people's well-being is raised and positive health benefits ensue. Both reductions in negative affect and increases in positive affect have been found to be related both to health behaviors and disease outcomes. However, there are many limitations in the existing literature on experimental interventions aimed at increasing SWB and assessing the effects on health. The time frame of when treatments that improve people's moods will actually produce tangible benefits to health and reduce the risk of mortality is not understood. Many psychological interventions seem only modestly effective because many of the health problems (e.g. smoking or obesity-related illness) may have occurred over such a long time that it is difficult to counter them. Also, it can be challenging to actually change people's long-term SWB because of the environmental and personality factors that may be impediments to change.

The majority of experiments designed to raise long-term SWB are focused on people with chronic medical or mental conditions. This leaves open numerous opportunities for future researchers to discover interventions that improve health

outcomes in healthy community-based samples. Interventions to reduce negative states such as depression, stress, and anxiety have received a vast amount of research attention from mental health researchers. However, newer studies also have been focused on raising positive emotions, and a number of these treatments are promising (e.g. Friedman et al., 2017; Kushlev et al., 2017; Moskowitz, Hult, & Duncan, 2012; Parks & Biswas-Diener, 2013; Proyer, Gander, Wellenzohn, & Ruch, 2014; Seligman, Steen, Park, & Peterson, 2005). Sin and Lyubomirsky (2009) present a meta-analysis of the SWB treatments' effectiveness in altering levels of SWB, and a number of interventions appear to have exerted a beneficial influence. Positive interventions, alone and in combination with treatment to also lower negative emotions, are an opportunity for health researchers to not only raise people's quality of life, but also to experimentally test the SWB and health connection.

As with all research approaches, there are challenges with intervention studies designed to raise well-being. Challenges of real-world experimentation include creating appropriate control groups, complications with random assignment to conditions, and differential attrition between the experimental groups. In addition, there is not yet a consensus on what interventions are most likely to lead to long-term improvements in SWB. It is not known whether treatments would be more effective if they were targeted at the requirements of individual participants rather than the current one-size-fits-all approach. The current studies investigating experiments designed to raise SWB are few, based on relatively small samples, and have not examined an array of health outcomes.

Shortcomings notwithstanding, the experiments altering long-term SWB have advanced the field of well-being and health by suggesting that improvements in well-being at least in some cases may improve health parameters. A number of recommendations can be made. First, much of the research takes a casual approach to selecting SWB interventions, without considering whether they are the most effective with this population. A serious shortcoming is that the interventions have often produced only small changes in SWB, and therefore it is not surprising when health outcomes are not found. Second, the time course of the interventions and outcomes needs to be carefully considered. Can changes in SWB alter the course of physiological indicators, or of disease manifestations in the time under study? Another issue is to consider which type of SWB should be the target of the intervention because it is likely to affect health. In some cases this might be life satisfaction or positive affect, and in other cases it might be the reduction of stress. Furthermore, SWB interventions that continue over time seem most likely to produce long-term results.

RESEARCH WITH NONHUMAN ANIMALS

Although research with animals has been very helpful in many health-related areas of research, this type of method is rare in the area of SWB. Animal studies

have several advantages, including generalising findings more broadly than only to humans. In addition, researchers with animals can often control factors that confound conclusions based on human research. Besides ratings from caretakers, animal emotional states have been assessed by methods such as cognitive bias measures, vocalisations, and physiological methods such as studying cortisol levels, cortical perfusion, and neuron activity. Behavioral indicators of well-being can also be assessed. For example, Harding, Paul, and Mendl (2004) showed that biased responding to stimuli can reveal negative emotional states in rats just as such biases do in humans.

Research on animal samples supports the link between psychological well-being and wound healing; rats which had an enriched environment and were not isolation-reared showed quicker wound healing than their counterparts (Vitalo et al., 2009). Conclusions from research on inflammation are confirmed by research on rodents suffering stress from social defeat, revealing an up-regulation of inflammatory markers (Powell et al., 2013). Chronic stress is widely known to negatively influence a number of health-related factors in animals, such as reduced reproduction (Moberg, 1985) and disturbed cardiovascular function (Henry & Stephens-Larson, 1985). Animals under stress are immune-compromised and therefore more open to disease (Marchant-Forde, 2015). In his popular book, *Why Zebras Don't Get Ulcers*, Sapolsky (1994) explains how short-term stress can be adaptive for animals in the wild, but can be detrimental to health when it is chronically felt over time. The animal findings support the conclusions from studies with humans, suggesting that stressful and negative states can interfere with healthy physiological functioning.

There is only a very small amount of animal research on positive emotions and health in the absence of chronic stress. Weiss, Adams, and King (2011) found that orang-utans rated as higher in subjective well-being by zookeepers (based on their estimates of positive moods, social life, and ability to reach desired locations, and reach desired objects) tended to live a human equivalent of 11 years more than the less happy apes (1 *SD* above versus 1 *SD* below the mean). The Ben-Shaanan et al. (2016) study on stimulation of the reward system and immune strength in rodents described in Table 6 is an impressive study of how positive feelings might be tied to health parameters. It is evident that work with varying levels of well-being in animals, including across the positive spectrum, is an area in need of future research.

MEDIATORS OF THE SWB AND HEALTH RELATIONSHIP

In order to fully understand how and why SWB affects health and longevity, the mediators of this relationship must be understood. That is, we need to understand what links the experiences of well-being to physical health outcomes. Ong (2010) reviewed a number of ways that SWB may influence health and mortality, and concluded that health behaviors (e.g. better diet, regular exercise, and

improved sleep), physiological systems (e.g. cardiovascular and immune systems), and stress (exposure or undoing) are primary candidates for mediators in the relationship. In terms of undoing the sequelae of negative emotions, research shows that positive emotions make people more resilient to stress, with the ability to bounce back in mood and physiology more quickly after a stressor affects their cardiovascular system (e.g. Fredrickson, Mancuso, Branigan, & Tugade, 2000).

It is imperative to discover what is happening physiologically that allows increases in SWB to ultimately manifest itself as better health. For example, high levels of well-being may positively alter cardiovascular function (e.g. heart rate), and those improvements in the cardiovascular system will ultimately lead to better health outcomes (Howell, Kern, & Lyubomirsky, 2007). The influence of different types of SWB may be mediated for different physiological systems by different intermediaries. For example, while the immune system might affect many different types of illness outcomes, the beneficial behavior of sunscreen use might most influence the decreased likelihood of experiencing skin cancer.

There are several approaches to uncovering mediation. First, we can use simple correlational methods, and use statistical techniques to determine whether a possible mediator can account for the covariation between SWB and health outcomes. An extension of simple correlational approaches is to test causal models, and often compare various possible models for the best fit. Causal models often include measures of a number of influences on health, as well as more than one possible mediator. They may also include several health outcome measures. By including a number of variables in the model researchers hope to gain a more realistic picture of how dynamic systems operate in the world. Furthermore, these approaches are capable of taking the error of measures into account in determining pathways of influence.

A second approach to determining mediation examines how SWB, possible mediators, and health vary over time within individuals. Data collection methods such as experience-sampling and ambulatory monitoring techniques have been developed to document physiological and SWB information in real time in the natural environment. In the momentary measurement methods, researchers can determine whether moods and various physiological parameters that might influence health change together in a predictable way within individuals.

Besides cross-sectional correlations and momentary ecological methods, short-term laboratory and ambulatory experiments demonstrate that manipulations of mood can be accompanied by health-relevant physiological patterns. The experimental methodology uses various tools (e.g. stimuli embedded in videos or tasks) to temporarily activate specific emotions in order to disentangle the relationship between the activated mood and other variables. The effectiveness of various mood manipulations is reviewed by Joseph, Chan, Heintzelman, Tay, and Diener (2017).

Cardiovascular System Mediators

Consistent associations are found between SWB and cardiovascular functioning, which in turn is related to health, cardiovascular events, and mortality. In Table 5 are listed examples of studies that explore the associations of SWB and physiological and health outcomes, and a few sample studies showing that the physiological measures are related to health. As can be seen, the association of SWB and cardiovascular health has been found for short-term emotions and physiological patterns at the moment that are beneficial to long-term health, as well as for long-term levels of SWB and cardiovascular health.

Immune System Mediators

In Table 6 we present example studies showing an association of SWB and immune measures, as well as a few studies revealing that immune function influences health. Based on these studies and others it seems plausible that boosted immune function is a mediating variable that helps explain how SWB influences health outcomes. In terms of theoretical explanations for the connection, Black and Garbutt (2002) explain why stress leads to inflammation, which can harm health when it is chronic. Pressman and Cohen (2005) outline how positive emotions specifically alter immune activity via endocrine, behavioral, and other activities.

Endocrine System Mediators

Certain hormones appear to be affected by SWB and momentary moods. Cortisol is frequently associated with stress and positive affect with lower levels of cortisol (Stephoe, O'Donnell, Badrick, Kumari, & Marmot, 2008), including in mood induction experiments (Buchanan, al'Absi, & Lovallo, 1999; Kirschbaum, Pirke, & Hellhammer, 1993). Brummett, Boyle, Kuhn, Siegler, and Williams (2009) found that positive affect was inversely related to levels of norepinephrine and cortisol after awakening. Insulin levels may also be affected by moods. For example, Skaff et al. (2009) showed that negative affect predicted rising blood glucose levels the next day, while glucose one day did not predict moods the next day.

The endocrine changes are relevant to the cardiovascular and immune changes discussed above. Sympathetic altering hormones (catecholamines) and hypothalamic pituitary adrenal cortical axis hormones such as cortisol play a role in regulating these other systems, and may be an early step in SWB altering the health-influencing mechanisms. There are other hormones that also could be important in the SWB and health connection but they are relatively understudied in this area (e.g. SWB and oxytocin and sex hormones). Finally, interesting hypotheses about cannabinoid receptors and endorphins may be relevant to positive emotions, but it is too early to determine how they might help explain the SWB and health association other than their connection to pain.

SWB and Telomeres

Telomeres are protective endcaps on DNA and they protect it from damage during replication. They become shorter as people age and telomerase helps rebuild telomeres. The two are important in maintaining cellular health and fidelity in terms of cell replication. While the degradation of telomeres is associated with cell senescence, lack of telomerase has been associated with conditions such as diabetes mellitus and poor insulin production. Stressful conditions have been found to be related to shorter telomeres in both children and adults (Drury et al., 2014; Epel et al., 2004). Children living in difficult, stressful conditions have been found to have shorter telomere length (Mitchell et al., 2014). Conversely, Jacobs et al. (2011) found that meditation was associated with greater telomerase in immune cells, and this was mediated by the effects of the practice on increasing feelings of control and decreasing neuroticism. The authors suggested that activities that raise people's sense of well-being can have substantial effects on fundamental physiological processes. Although it is early in the history of research in this area and there are few studies, the findings are promising in offering a direct tie from psychological well-being to aging and health at the cellular level.

SWB and Wound Healing

Wound healing is interesting because it involves a number of different systems working together in an intricate pattern. Although it is often included with immune functioning because this is such a core part of healing, other processes are also involved. In order for wounds to heal, usually vasoconstriction and inflammation are involved, but also revascularisation must occur, collagen support and tissue growth must take place, and all these must occur in a specific order over time. One study found that the process of skin-barrier recovery was faster for individuals who had greater positive affect (Robles, Brooks, & Pressman, 2009). It has also been found that surgical patients heal more quickly if they are high in life satisfaction (Kopp et al., 2003). Kiecolt-Glaser, Marucha, Marlarkey, Mercado, and Glaser (1995) found that women caring for a patient with Alzheimer's Disease healed more slowly from a standardised wound compared to matched controls. Rats raised in an enriched versus isolated environment show faster wound healing (Vitalo et al., 2009).

In individuals recovering from surgery, those who receive psychological interventions such as guided imagery, breathing exercises, or stress management training were found to heal more quickly (Broadbent et al., 2012). Married couples in an experimental paradigm healed more slowly when they were in the conflict condition than in a supportive interchange condition (Kiecolt-Glaser et al., 2005). Dental students who were given a standardised wound healed more quickly during the summer compared to while undergoing the stress of final examinations (Marucha, Kiecolt-Glaser, & Favagehi, 1998).

Health Behavior Mediators

People high in SWB often perform healthier behaviors, and this mediational pathway may be a major cause of their greater health and longevity. In Table 7 we present examples of studies on SWB and healthy behaviors. The table shows that SWB has been found to be associated with health behaviors in many studies. Although a few experimental studies have examined changes in SWB and the changes in health behaviors that might ensue, more research of this type is needed.

In sum, there appear to be a number of mediational pathways through which SWB affects health: cardiovascular, immune, wound healing, telomeres, endocrine response, and health behaviors. In light of the number of physiological processes influenced by moods and SWB, it would be surprising if there were not health outcomes deriving from SWB.

MODERATORS

When does SWB influence health and longevity, and when does it not? Across studies SWB and health and longevity are often, but not always, related. For instance, DuBois et al. (2015) reported that in 65 per cent of the studies they reviewed a significant association was found after adjusting for one or more covariates. Thus, in about one-third of the studies a significant association was not found, and this raises the issue of moderation. In some cases the nonsignificant association could be due to lack of statistical power and other methodological considerations. However, in others it might be that no association existed. Thus, it is important to identify the conditions that must be in place to allow the SWB and health connection to exist so we can gain a better understanding of the factors that circumscribe when a causal association is actually found. These factors are referred to as moderators.

It is likely that the relationship going from SWB to health and longevity varies across various groups and conditions. For instance the relationship between SWB and healthy behaviors could be attenuated in subcultures that strongly proscribe unhealthy behaviors such as smoking because virtually all people, regardless of their SWB, conform to the healthy normative behavior. There are also potential cultural differences in the SWB and health connection, for example, due to what emotions are considered normal or are valued (Curhan et al., 2014; Miyamoto et al., 2013). For instance, in East Asian cultures calm positive emotions are preferred over aroused ones, whereas the opposite is true in individualistic nations such as the USA. Thus, it might be that calm emotions are more helpful to health than aroused ones in East Asian societies. Similarly, because pride is desirable in some cultures and proscribed in others, it might have very different associations with health. Kitayama, Park, Morozink Boylan, Miyamoto, and Levine (2015) found opposite associations between anger expression and cardiovascular, immune, and cholesterol indicators in the USA and Japan. The

authors hypothesised that anger expression is linked to higher status in Japan, and that this could be why it is associated with beneficial physiological patterns in that culture. The area of culture differences in the SWB and health association is wide open for needed research.

Moderation by the Population Sampled and Geographical Region

Age, sex, and other characteristics of the population have served as moderators of the connection between SWB and health outcomes. Examples of studies finding moderation effects are presented in Table 8. As of yet, compelling explanations of the sex and age differences in the findings have not been offered. Studies of ethnic differences in the SWB and health association are so rare that we do not hazard a guess as to their causes.

Moderation by the Type of SWB

Another moderator that seems to influence when SWB will affect health is the type of SWB involved, for example optimism versus life satisfaction versus negative affect. Examples of studies analyzing moderators of this type are shown in Table 9. It can be seen, for example, that in some instances positive or negative affect are associated with health outcomes independently of SWB of the other valence. One challenge in separating the effects of various types of SWB is that they are often substantially correlated. Thus, untangling their influences statistically requires very large samples, and unfortunately many existing studies are underpowered to reliably disentangle the correlated moderators. Although there are data to suggest that positive and negative affect can exert separable influences, with positive affect sometimes exerting beneficial effects and at other times negative affect exerting detrimental effects. We do not yet understand the conditions where each might exert the strongest effects, and why. In addition, it is uncertain whether the means and distributions of the types of SWB are responsible for the effects that are found. The samples could vary more substantially on one type of SWB than on another, for example, but researchers have not examined this possible explanation. Furthermore, for variables such as life satisfaction, optimism, and enjoyment of life we have virtually no knowledge of the separable versus overlapping effects. There is some indication that highly aroused positive affect might be harmful to health compared to less aroused and intense forms of positive affect.

Moderation by the Specific Health Outcomes

Different health outcomes might be differentially affected by SWB. For example, depression likely influences deaths by suicide, but it seems less likely that it

would affect deaths by certain genetic diseases. Similarly, positive affect might benefit the immune system and thus help ward off some infectious diseases such as influenza, but not counter the effects of others.

In terms of moderation by type of illness, Wikman, Wardle, and Steptoe (2011) found that strokes were associated with substantially lower SWB, whereas diabetes and cancer were least associated with low SWB. Howell et al. (2007), in a meta-analysis of 150 experimental, ambulatory, and longitudinal studies, found that affect appeared to influence pain levels, disease progression, longevity, and immune strength, but not cardiovascular health or endocrine system responses. For health status, well-being had a greater impact for both short- and long-term outcomes in healthy samples. However, well-being more strongly influenced unhealthy samples in countering disease and increasing survival.

Hoehn, Denollet, de Jong, and Whooley (2013) found that positive affect predicted lower levels of all-cause mortality in patients with coronary artery disease, but not cardiovascular events. Similarly, Shirom, Toker, Jacobson, and Balicer (2010) found that in a sample followed for 20 years (mean age initially was 41.7 years) feelings of vigor predicted lower mortality and diabetes, but not ischemic heart disease. Kroenke Seeman, Matthews, Adler, and Epel (2012) found that positive affect predicted prevalent coronary artery calcification 15 years later, but not to progressive calcification at 20 years follow-up. Because health outcomes cover such a wide range of states—from overcoming cancer to catching a cold—we need to more carefully analyze the type and intensity of illnesses that are likely to be influenced by SWB, and why.

Moderation by the Study Characteristics

Some meta-analytic reviews point to different outcomes in studies that differ in the research methods used. For example, Howell et al. (2007) found that ambulatory studies in which subjects were followed across days produced the least strong findings, and experimental designs the strongest effects. They suggested that in the ambulatory short-term studies across days that other factors such as life events might swamp the effects that can be seen in long-term patterns, whereas in experimental studies a greater number of extraneous factors may be controlled.

Measurement is another methodological factor that can influence whether an association is found between SWB and health. For instance, Steptoe, Gibson, Hamer, and Wardle (2007) found that positive affect measured by experience-sampling was related to several physiological indicators of healthy functioning, but a global measure of positive affect was less often related to these same parameters.

In summary, moderators thus far have been somewhat inconsistent across studies and health outcomes, and there have been few systematic attempts at strong conceptual understanding of the moderators. For instance for age and for

sex we do not have a clear picture of the when and why they influence the association of psychological well-being and health, and this is also true of the other moderators as well. We need more systematic analyses of different outcomes resulting from different measures, methods, and distributions and mean levels of the types of SWB before firm conclusions can be reached about possible moderators in this realm.

SWB AND HEALTH EMBEDDED IN A COMPLEX DYNAMIC SYSTEM

Behavior exists in complex systems where each outcome is influenced by a number of other variables, and in turn influences other variables. Furthermore, at times a variable is both influenced and influences another variable. A full understanding of an association such as that between SWB and health must include a consideration of bidirectional influences, reverse causation, and both distal and proximal influences.

Multiple Causation

It is evident that health and longevity are influenced by many factors, both genetic, behavioral, and physiological. These factors may be more distal or more proximal from health outcomes. For example, income is a more distal influence on health that can have an influence through more proximal influences such as SWB, the quality of medical care, nutrition, and perhaps feelings of respect and status. Social relationship variables such as social support versus loneliness can influence health through social effects on health behavior, as well as possibly on more direct effects on physiological indicators relevant to health.

A challenging issue is that many of the more distal factors such as income can influence both SWB and health. Part of the challenge comes in that if these variables are controlled as possible confounding variables, this might statistically over-control because it removes portions of SWB that are relevant to health (discussed further below).

Another issue with variables such as income and social support is that SWB not only is influenced by them, but also is known to influence them. A number of studies show that people high in SWB later earn higher incomes and have better marriages, for example, and these associations have been replicated a number of times. Thus, the danger with the automatic statistical control of these variables is that this can control away significant and influential portions of SWB.

For behavioral phenomena we can always locate distal influences, those occurring in the past or at a distance, and proximal indicators that are closer to the outcome in space and/or time. The distal–proximal distinction is important in the SWB and health domain because some of the variables that are often controlled as possible confounds in correlational and longitudinal results could be

causes of SWB (and it mediates their effects on health), outcomes of SWB (and they mediate its effects on health), or they might directly influence health. Income is a prime example of a variable that can both foster SWB, and in part result from it. Thus, simply controlling income as a confounding nuisance variable, although informative, can be dangerous if not carefully considered within a distal–proximal conceptual analysis. In analyzing statistical corrections there is a danger of controlling away valid SWB effects.

Reverse Causation: Health Influencing SWB

Because health can influence SWB, a challenge arises in the difficulty of separating effects in each direction. When we examine longitudinal studies we find evidence for an association between worsening health and declining SWB. For example, Hubbard Goodwin, Llewellyn, Warmoth, and Lang (2014) found a strong negative correlation between frailty and SWB in an elderly sample. Binder and Coad (2013) studied over 100,000 individuals in the British Household Panel Survey, and used propensity-matching to create “treatment” and “control” groups. In this study, decreases in health such as stroke and cancer predicted lower SWB.

Acute infection can trigger major depression (Gunaratne, Lloyd, & Vollmer-Conna, 2013). A small amount of experimental work also suggests health effects on SWB. Janicki-Deverts, Cohen, Doyle, Turner, and Treanor (2007) infected volunteer participants with a virus and quarantined them. Daily production of proinflammatory cytokines was related to lower positive affect the next day, but was not related to negative affect. In another study, those receiving a typhoid injection were lower in mood several hours afterward, compared to the control condition (Strike, Wardle, & Steptoe, 2004; Wright, Strike, Brydon, & Steptoe, 2005).

Several characteristics of an illness may increase the impact of health on SWB, for example whether it interferes with activities of daily living. Mukuria and Brazier (2013) found that ability for self-care, ability to carry out usual daily activities, and pain were all aspects of health that are related to reports of happiness. Graham, Higuera Jaramillo, and Lora (2011) found that both interference with daily activities and pain were associated with lower SWB. However, the researchers also found effects that suggest that expectancies moderate the effects of health on SWB. For example, they found that difficulties with daily activities had less impact on older respondents. Income lessened the impact of pain on life satisfaction, but made difficulties with self-care more impactful. The authors suggest that the latter finding is due to the fact that wealthier people have higher expectations in general. Finally, they found that mobility problems had a larger negative effect on men than on women.

The impact of ill-health on SWB is not a linear function of the objective illness, but seems to be heavily influenced by overcoming disability to stay involved with other people and activities. It is important to note, however, that it

is possible that the individual's level of SWB is one key determinant of whether they stay involved with others and continue to work and function well. The path from health to SWB is frequent enough that it must also be considered and analyzed when studying directionality between SWB and health.

Third-Variable Explanations (Confounding Variables)

Apparent causal influences might be due to some third confounding variable. In the case of SWB and health, there are several culprits that deserve examination. Sociodemographic factors, genetic predispositions, early nutrition (including pre-natal nutrition), social relationships, and other factors must all be considered if we are to uncover the true nature of the SWB and health connection.

One type of third variable that is sometimes overlooked is that of the measures containing artifacts that might contaminate them and lead to misleading conclusions. For instance, when SWB is assessed by self-report surveys and health is also assessed by subjective ratings of health, there is an obvious problem of contamination of both measures by factors such as social desirability, positivity, and response biases such as number use, leading to a spurious association between the two. Even more problematical, sometimes self-report measures of health include items such as vigor and energy that are also included in measures of SWB. For this reason it is important to examine experiments in which SWB or moods are induced, which do not then rely on participants' reports of their moods, and to also examine objective tests of health such as biological and health markers. Objective assessments of health behaviors such as activity tracking and prescription compliance also are very desirable. In the measurement of SWB we can examine nonself-report measures such as SWB reports on the target participant obtained from knowledgeable informants, cognitive and response-time measures, experience-sampling, and daily reconstruction measures (DRM) of moods. More diverse methods for assessing SWB would obviate some concerns about measurement confounds leading to spurious conclusions.

One approach to ruling out the influence of third variables is through statistical controls or similar strategies such as participant-matching. An example of statistical controls, and the issues they present, is the study by Liu et al. (2016) on the Million Women sample in the United Kingdom. The investigators followed a large sample of women for 10 years after they had responded to a single-item 3-point happiness scale and observed mortality. The initial happiness measure did predict longevity, but did not withstand the control variables that were then employed—statistical controls for self-reported health, treatment for anxiety, arthritis, asthma, depression, diabetes, or hypertension, and several sociodemographic and lifestyle factors (such as smoking, deprivation, and body-mass index). One issue of such controls, as discussed below, is that they controlled the effects that SWB had exerted to that point in time, at about age 50, and thus discarded these effects. Another issue is that factors such as smoking and

hypertension can be influenced by SWB, and thus controlling these variables can lead to an underestimation of the effects of SWB on health. One more issue is in controlling subjective health, the reports of which are likely to be influenced by a respondent's happiness and positivity, the investigators controlled away valid portions of SWB. Segerstrom (2014) found that both negative and positive affect could in some instances influence reports of self-rated health beyond the effects of objective indicators of health. Furthermore, it is remarkable that the findings were as robust as they were, in light of the fact that the measure of SWB used was not ideal. These issues with statistical controls are discussed below.

The Challenges of Statistical Control

The association between SWB and health might be because health influences SWB or because third variables such as income influence both of them. In order to determine whether SWB actually influences health, researchers often turn to statistical controls in which the possible confound is eliminated statistically and the resulting association examined. For instance, to rule out the possibility that SWB is associated with longevity only because it is influenced by the person's health at the initial testing, health status at that time is controlled in the association between initial SWB and longevity after that. However, there are a number of serious issues when statistical controls are employed, and these often go unrecognised. For instance, statistical controls can substantially alter the nature of the questions being asked. Below we describe issues with statistical controls. The first was discussed by Kahneman (1965) and the next two were discussed by Meehl (1970). The final issue comes from our observations of research on well-being and health. Readers are referred to those original sources, as well as to Westfall and Yarkami (2016) and Rohrer (2017).

Undercontrol Because of Error of Measurement. When statistically controlling variables usually we do not control away the full amount of variance that is due to those variables because they are measured with error. Thus, in controlling for Time 1 health, for example, our control will be incomplete to the extent that our measure of health contains measurement error. Our measure of SWB is also likely to be affected by measurement error. For example, if a relatively weak measure of positive emotions is used, the underlying true associations might be seriously underestimated. Corrections for the attenuated reliability of measures are rarely conducted in this literature. This means that we do not fully capture the effects of SWB, or of the potential confounding variables either, when simple statistical controls are introduced in the analyses. Because most studies rely on brief self-report measures of SWB, often collected at only one point in time, underestimation is usually a distinct possibility. A measure of SWB taken at a single point in time will only partially capture the long-term effects of SWB on health because SWB does not remain completely stable over time.

Failure to correct measurement error in some cases can even produce illusory positive findings. If a predictor is measured without error, such as the treatment condition, and is not related to the outcome variable, it might appear to be associated when potential confounds are statistically controlled if they are not corrected for measurement error. Thus, not controlling for measurement error can lead to both over- and under-estimation of effects in some instances.

Systematic Unmatching and Unrepresentative Subpopulations. Statistical control is similar to matching of subjects because we match people statistically to compare people who are similar on the control variables and yet differ on the independent variable. For example, in controlling Time 1 health, we seek to identify people who are similar in health but different in SWB when we predict longevity. The problem is that SWB must be caused, and when one of those causes, for example health, is omitted from the system, other factors influencing SWB must then differ. It is likely that some factor such as temperament must then differ to make some people just as happy when they are ill as others are when they are not ill. Meehl (1970) explains how statistical controls match subjects on the variables in question, but then unmatch them in an unintended way on other variables. He also explains how statistical controls are likely to make the sample less representative than it was before controls were introduced, by weighting certain unusual individuals more than the more typical ones.

Causal Arrow Ambiguity. A serious issue is that when we control for a possible confounding variable, it might over-control because it is itself a cause or an effect of the independent variable, and therefore controlling it removes some amount of the effect of the predictor. For example, controlling for health at Time 1 because it is a possible confound overlooks the fact that it might at that time also result from SWB. Therefore, when it is controlled it removes valid predictive power from SWB.

In order to separate the direct effects of SWB on health, as well as estimate the mediated indirect paths, one should use longitudinal measures with path analysis in a cross-lagged design. This procedure is needed both to examine the effects of SWB on outcomes, but also to assess third variables that might confound the results, or that might arise from SWB or lead to it. Only by using more sophisticated research designs can researchers hope to accurately estimate the various biases and influences.

It happens very frequently that investigators in this area control socioeconomic variables such as income and education, without realising that factors such as income can be themselves influenced by SWB. There are now studies showing that people high in early SWB are likely to later earn higher incomes, for instance, even when controlling factors such as parental income. Thus, in controlling income the researchers are possibly throwing out valid portions of SWB that might be influencing health.

In behavioral research a number of third-variable patterns are recognised and discussed, including third variables as suppressors, mediators, causes, and outcomes. In the case where third variables cause both the independent and dependent variable they may be confounds when trying to estimate the causal effects of the independent on the dependent variable. However, there is a danger of over-control in which actual effects are deleted. For third variables that may cause both SWB and health, it is informative to examine both their direct effect on health, but also their indirect effects through SWB. It is important to note that when third variables are mediators or outcomes it can often lead to misleading results when they are controlled. What is important is that a conceptual analysis of the system be consistent with the way the controls are employed. A strength of causal modeling, described below, is that the potential confounds can be introduced into the analyses in terms of different possible relationships, and the results determined. In this way one can be more certain that the researcher is not spuriously controlling away true relationships. Furthermore, causal analysis demands that researchers carefully consider the pathways that may exist between the variables they measure.

Studying Change in the Rate of Effects, Not Effects Per Se. Scientists must consider the time course of disease progression. For instance, if a sample begins at age 60 and beyond, substantial cardiovascular damage is likely to already have occurred in many participants. Thus, if researchers control for Time 1 health they may inadvertently over-control in the sense that they eliminate possible detrimental effects of low SWB that might have occurred over many decades, and might also control away future damaging effects of low SWB because these will be highly related to the rate of damage that has already occurred. When we control Time 1 health we jettison potential earlier effects of SWB on health from our analysis. Not only that, but we diminish the likelihood of uncovering further effects of SWB that continue at the same rate as before. By controlling Time 1 health we essentially now examine whether the rate of SWB's influence on health is changing after that point in time, not whether the level of SWB is influencing health. In controlling Time 1 health we thereafter will only uncover effects when they occur at a greater rate than previously. We have altered the question the statistics answer from whether SWB can influence health, to whether it does so at a different rate than it did previously. The fact that so many studies have shown positive results even after controlling Time 1 health might mean that the effects of SWB on health do increase with age.

The current standard practice of control might be more informative for diseases that occur quickly without prior conditions that point to them. In this case, controlling health at Time 1 may make sense. In this case the course of illness is abrupt and discontinuous, and therefore controlling for T1 health does not throw out all the earlier influences of SWB. However, for many diseases there is a progression of the condition over many years, even decades. The condition might

only become fully evident and full-blown at some point in time, but the physiological conditions underlying it might have progressed throughout adulthood and to some degree be captured by Time 1 measures of health. In this case controlling for T1 health truly can lead to misleading results.

A further complication is that when one examines the predictive power of SWB at Time 1 on later longevity, it must be recognised that not only are the Time 1 measures a snapshot at that time that does not capture SWB during all the prior years, and which could have affected health during those years, but also that SWB might change after Time 1. Fujita and Diener (2005) found that a significant number of individuals change substantially in well-being over a period of years. Thus, Time 1 SWB might not fully predict longevity in part because it rose or declined over time, and also a measure at one point in time does not fully capture the long-term effects. Thus, highly reliable measures and ones that occur over time will be needed to fully capture SWB's effects on health. When mediocre measures of SWB are employed at one point in time, they cannot be expected to fully assess the influences that might be occurring.

CONTROLLING POTENTIAL CONFOUNDS

Concerns about statistical over-control in behavioral research have been expressed by others (e.g. Spector, Zapf, Chen, & Frese, 2000) because of the possibility of throwing out phenomena by inadvertently erasing their effects. However, in the fields both of SWB and health these concerns have not received widespread attention. Researchers must fully understand the conceptual and statistical implications of the controls they use. It is not that controls should never be employed, but they must be implemented cautiously, and their limitations fully appreciated. In light of the strong effects statistical controls can exert, and their ability to over-control away true associations, it is remarkable how frequently significant effects have nonetheless been uncovered.

Caution alone is not enough to wisely use statistical controls. For instance, we can employ methods when we control variables that take measurement error into account. We can be certain that we know the variables employed are in fact likely to be confounds. For instance, if we control various types of maladies at Time 1 because they might be confounds by influencing SWB, we should know that in fact these conditions do influence people's well-being. Without such knowledge the risk of over-control easily outweighs the risk of confounding. For example, in the Liu et al. (2016) study described earlier, the investigators should have determined whether hypertension and diabetes affect SWB before controlling them as possible confounds. Similarly, researchers should understand how objective health differs from subjective reports of health, so they know how much potential variance in SWB might be erased by controlling the subjective reports versus simply controlling objective health measures.

Statistical controls represent a theoretical statement about the structure of the dynamic system, and are not simply a way of removing confounding variables. It may be that in fact using statistical controls does not distort findings in particular cases, and does help control confounding variables. However, this happy circumstance cannot be assumed without understanding and carefully analyzing each of the associations between all of the variables used in the analyses.

We suggest that statistical controls can be more problematic and challenging than most researchers have realised. They do not magically solve the problem of confounding variables. What is a researcher to do in this case, when confounding variables obviously often may represent a problem? First, statistical controls should be presented and interpreted carefully. Not only should the simple zero-order correlations among all variables be presented in all research reports, but controls should be entered in a way that allows examination of each of their separate influences. In this way, readers can gain a clearer picture of the associations involved. When only final regression analyses are reported, it is impossible for readers to fully understand the associations between the variables.

Third, investigators can employ alternative strategies and methods that take potential confounds into account and possibly control them, but in meaningful ways. For example, one can obtain reports of SWB at an early age, and then not examine mortality until many years later. This greatly reduces the risk that Time 1 health was a confound because it had been influencing SWB. If the sample is not tracked until some duration after the Time 1 SWB measures were obtained, it is less likely that health had much effect on SWB at that time. For instance, in the well-known nun study by Danner, Snowdon, and Friesen (2001), the autobiographies on which the SWB scores were estimated were collected around age 22, and the nuns' mortality was not tracked until after they reached 75. Thus, it is unlikely that health had much effect on the early assessment of SWB because the nuns in the study all lived for 50 or more years beyond that time before the tracking began. Similarly, Steptoe (2016) assessed enjoyment of life, but did not begin tracking mortality in the sample until two years beyond when the initial measures of SWB were collected. In the ensuing eight years he found one-third the mortality in the highest compared to lowest enjoyment of life group. In this way Steptoe lowered the likelihood that Time 1 health was not exerting a profound effect on SWB at Time 1 because his sample did not include those who died in close proximity to the measure of well-being.

Another way of controlling possible confounding variables is to examine data that are experimental or quasi-experimental in nature. For example, one can examine whether physiological and health measures are influenced by experiments designed to raise people's SWB. One can examine whether stressful events that cannot be attributed to the subjects' individual characteristics, such as war or an earthquake, affect people's SWB and in turn their health. People whose SWB is raised by a random event such as winning the lottery could be examined in terms of their health thereafter.

Researchers have also controlled for certain confounding variables by studying twins, and employing statistical controls. Genetic studies that utilise the identical chromosomal make-up of twins can help rule out genes as the sole cause of the health and SWB relationship. Sadler, Miller, Christensen, and McGue (2011), for example, found that SWB was related to increased longevity in identical twins. Because SWB predicted longevity even between identical twins, the results indicated that the relation between SWB and longevity cannot be entirely due to either genes or shared family environment. Animal research is another way to overcome the potential confounds that often occur in studies on humans.

CAUSAL SYSTEM MODELING

An additional method for exploring complex systems is causal modeling, which is a statistical approach in which the empirical data are fit to a model of interconnected variables, and the goodness of fit can be judged. Improvements to the fit of the model can be calculated when paths of direct and indirect influence are added or eliminated. Alternative plausible causal models can be tested against one another. When data are longitudinal, causal direction can be explored by comparing the fit of models that move in either direction over time. In this way, factors such as income that might be potential confounds, but also might result in part from SWB, can be included and yet not simply controlled away in a fashion likely to spuriously introduce errors of inference. One feature of causal modeling is that it can employ multiple measures of variables and analyze the data using Structural Equation Modeling, in which case the effects of measurement error can be assessed and obviated.

To adequately conduct strong causal modeling a conceptual framework is needed that posits relationships between each of key variables that can influence and be influenced by SWB and health, as well as potential confounding variables. Both direct and indirect pathways by which SWB can influence health must be specified. Although it is never possible to assess all the potential confounding variables, the major ones need to be identified. For an introduction to causal modeling, readers are referred to sources such as Imbens and Rubin (2015) and Mayer, Thoemmes, Rose, Steyer, & West (2014).

An important ingredient for strong causal modeling is that the important variables in the model are assessed repeatedly over time. For example, to determine the causal direction between SWB, health behaviors, and health outcomes, at a minimum the researcher should have a measure of SWB at T1, a measure of health behavior somewhat later, and a measure of health at T3 following that. Furthermore, if each of the variables is assessed repeatedly at each of the time points, it allows not only predictions from the levels of each variable, but also from their change over time. Ideally of course this will include multiple points in time, not just three.

We know of no studies that have examined full causal models in which the pathways going from SWB to the mediators and to health outcomes, as well as possible confounds (that might also cause or be influenced by SWB), have been tested simultaneously in the same specified model. Furthermore, we know of no studies that simultaneously measure factors beyond SWB, such as social support, that are thought to influence health but also influence and can be influenced by SWB, so that the direct and indirect effects of them in combination with SWB can be assessed. For example, does social support influence health because it raises well-being and lowers stress, or does SWB influence health because it makes people more sociable?

Causal parsing also has not been conducted with a broad set of SWB variables simultaneously, including optimism, life satisfaction, stress, and enjoyment of life, for example, with large samples to determine the common and unique effects of these well-being variables on health. Although positive and negative affect have been shown to have unique associations with health, an assortment of types of SWB have not been carefully separated using sufficiently large samples. To strongly determine the separate effects of various forms of SWB, analyses are required that include corrections for measurement error. Causal modeling with longitudinal data, as well as experimentation in which the causal factors are each varied, are needed to help understand the full causal system going from psychological and social variables to health.

NEEDED RESEARCH

We began the review by asking whether SWB influences health and longevity. In light of the review we can now give greater focus to this question. We now know with some degree of confidence that SWB *can* influence health-relevant biological indicators, health, and longevity, at least in some instances. We have strong leads on several explanations of how SWB affects health. We also know that SWB is neither a necessary nor a sufficient cause of health because other factors clearly influence health, and even in the absence of high SWB some individuals are healthy. A major unanswered question now is when SWB does and does not influence health. Much more research is needed, but certain areas seem to be particularly understudied.

1. We need much more moderator research in which the factors that alter the relationships between SWB and health are studied. As it now stands we have inconsistent findings, for example that SWB is related to a health outcome for one sex, but not for the other. Furthermore, these moderators sometimes reverse from one study to the next. We have little understanding of these findings, and many other potential moderators remain unstudied. This area demands much more in-depth study and theoretical development.

2. Research is needed that examines the common and unique influences of the various forms of high and low SWB, for example, life satisfaction, positive

affect, optimism, and stress. Many but not all researchers now recognise the importance of assessing not just negative emotions such as stress and depression, but positive emotions as well. A few studies include life satisfaction, optimism, and other related variables as predictors as well. Because these measures are inexpensive and quick to include, they should be employed more frequently. We know that positive and negative emotions appear to have separable effects, but we know little about the differential effects of other types of SWB. However, because these variables tend to correlate, sometimes substantially, very large samples are needed to reliably pinpoint their unique effects.

Research is also needed on the measures being employed. Different measures may tap different aspects of the underlying concept, and therefore produce results that could differ from other measures of supposedly the same variable. For instance, the widely used PANAS (Watson, Clark, & Tellegen, 1988) scale of positive and negative affect focuses on the experience of highly activated and intense emotions (e.g. excited and enthusiastic). Other scales often assess less aroused forms of positive emotion such as happiness or contentment (Diener et al., 2010). It is possible that positive emotions are generally beneficial to health, but highly aroused ones may be detrimental (e.g. Pressman & Cohen, 2005). Therefore, measures of positive affect should not be assumed to be identical. Positive feelings have been assessed by cheerfulness and sense of humor, and by the enjoyment of life and other measures as well. There may be overlapping influence between many of these concepts but we cannot be certain until this is tested. It could also be that some of these measures capture more activated and aroused feelings, whereas others capture calm and contented feelings, and the two might have distinctly different effects on health. Furthermore, one-time global self-reports of SWB might differ from well-being captured by experience sampling measures or informant reports of SWB.

The level of SWB that most benefits health deserves more extensive study. Are there threshold effects, above which SWB no longer benefits health? Are there levels of SWB such as highly aroused positive affect that can harm health, and how might they do so?

3. The time course of various health outcomes is also important to consider in terms of the influences of SWB. Some outcomes might slowly accumulate over many years, such as the build-up of arterial plaque. Other outcomes, such as stress-induced tachycardia, might be immediate, and yet depend to some degree on earlier unhealthy developments over decades. Similarly, some causes of health or illness occur over long periods of time, for example the effects of health behaviors such as using sunscreen and healthy nutrition. Other outcomes may depend on immediate mood, yet in combination with physiological patterns in the person that have been laid down over a long period of time. Sorting out these differences both theoretically and empirically should be a goal of future research, requiring that measures be administered repeatedly over time.

4. More experimental research is needed on interventions in which long-term positive psychological states are raised and the effects on health assessed, including in populations who are not suffering from ill-being. The long-term experiments are particularly valuable in establishing the causal impact of SWB on health. Even in the realm of treatments to reverse states of ill-being such as depression and anxiety much research is needed. Studies in which well-being is raised in normal populations will help shed light on optimal levels of well-being.

5. Third variables such as prenatal effects and childhood environmental effects need to be examined in terms of whether they are, at least in part, responsible for the SWB and health associations that have been found. Could it be that the early environment, including factors such as prenatal nutrition and stressful early family conditions, can influence both later SWB and health through the adult lifespan? If so, how much do these effects explain the SWB and health connection? Although some variables such as SES have been studied frequently and controlled, other possible explanatory third variables remain understudied.

6. Much more research is needed to parse the interacting effects of variables such as income and social relationship quality, which can be influenced by SWB but also influence SWB. Exploring these variables together with SWB is needed to understand whether they directly influence health, or do so by influencing SWB, which in this case is the mediator. There are a large number of variables that can influence health, but which co-occur with SWB. Sleep is a prime example. It can influence health and SWB, but SWB can also influence it. Thus, sophisticated designs are needed to disentangle its effects separately from the effects of SWB, and this is true of other variables such as income.

7. More nonhuman animal research will be informative, especially on the effects of well-being on health. A number of studies on animals have examined the influence of stress on health, but few have examined whether felicitous circumstances that would be thought to induce positive feelings influence animal health. One reason that animal research adds to experiments and other research with humans is that conditions can be more fully controlled with animals, and certain third-variable explanations ruled out. In addition, the interactions of genetics and SWB can be studied. Fortunately, there has recently been increased interest in assessing the emotions of animals, and these methods may prove useful in the SWB and health domain.

8. In terms of assessing SWB, it would be desirable to move beyond one-time self-report survey measures in assessing SWB. Not only would it provide more reliable measures if SWB were to be assessed at several points in time, but it would also be potentially helpful to add other types of measures beyond simple self-report surveys. Neuroimaging methods, experience-sampling, as well as approaches such as informant estimates of the SWB of the target respondent, memory and reaction-time cognitive measures, facial and nonverbal expression measures, and assessments of emotional expressivity skills would be helpful to add to our research armamentarium. The advantage of multiple assessment

methods for measuring SWB is based on the premise that none of them are perfect, and each contains some error of measurement. Thus, using latent traits of combined measures could produce more valid measures. Furthermore, concerns with self-report measures such as their confounding overlap with other measures can be reduced by including nonself-report measurement methods.

9. More causal modeling of multiple influences on health needs to be conducted, in which direct and indirect pathways from SWB to health are analyzed. Factors that may influence SWB and/or health should be included in these analyses to more carefully parse their effects. Because of the simpler statistical approaches that have characterised the field, many existing data sets could be revisited with more sophisticated analyses.

10. If we can uncover the process by which brain states are related to emotions, and feelings of well-being influence the endocrine, immune, and cardiovascular systems, it might be possible to mimic those states physiologically in people who are not readily responsive to well-being interventions.

11. Cultural differences in the SWB and health connection are wide open for research. The few studies conducted to date suggest that there may be differences in the effects of certain emotions on health, depending on cultural context.

APPLIED VERSUS THEORETICAL ISSUES OF THE RESEARCH

The question of when and how SWB affects health is of both theoretical and applied importance. For healthcare practitioners the evidence now seems sufficient that in some cases they may be concerned about the SWB of their patients. Naturally, when patients suffer from problems such as depression or anxiety disorders, a referral for proper treatment is advised. However, with certain disease groups such as cardiovascular disease, interventions to raise the well-being of clients and reduce their stress now seem justified. Although our evidence base is not beyond a reasonable doubt, the preponderance of evidence suggests that at least some individuals would benefit from having higher SWB. Current evidence also suggests that in routine medical check-ups screening not only for negative emotional states, but also for low positive ones, might be helpful. Furthermore, interventions are now being tested that may raise well-being in much less costly ways than traditional individual psychotherapy. However, the evidence base at this point is too sparse to strongly recommend that assessments or interventions for high SWB become routine parts of healthcare practice. Further, there are complicating factors that must be explored such as the potential detrimental effects of high-arousal positive affect.

For research scientists, the field is wide open for needed advances with applied implications. When does SWB influence health, and when will increases in well-being further benefit health? Are there physiological and behavioral patterns evident in happy individuals that we could raise in a direct way even when increasing SWB might be difficult or costly?

SUMMARY AND DISCUSSION

To the question of whether SWB *can* influence health, at least in some instances, we answer in the affirmative with some degree of certainty. To the question of how this occurs, we now have initial answers, for example, in terms of health behaviors, and the immune and cardiovascular systems. To the question of when this occurs and when it does not, and where it is most likely to occur, we as yet have only scattered initial hypotheses, and this is one of the big directions for future research. To the question of how large the effects are we have some initial estimates from scattered studies, for example in terms of extra years of life and odds-ratios, but to our knowledge no systematic reviews and analyses have been conducted. How do the effects of high versus low SWB compare, for example, to the beneficial effects of exercise or not smoking?

We know little yet about whether interventions to directly raise well-being will improve health and longevity. The results of such studies so far have been mixed, perhaps in part due to the difficulty of raising long-term SWB in a non-trivial way. We do not know if there are threshold effects beyond which increases in SWB do not have benefits. Finally, there are potential third-variable explanations of the effects, for example prenatal nutrition, that have not yet been ruled out. Thus, we have some answers to various aspects of SWB causing health outcomes, but there is much more to learn.

Our review suggests that encouraging progress has been made in our scientific understanding of the well-being influence on health, but many important and intriguing research questions remain. The reviews makes clear that we need to know more than the simple experimental question framed as to whether SWB has a causal influence on health. We are now moving beyond the initial stages of research in this area where exciting associations have been uncovered, to more sophisticated approaches that can identify the full set of conditions when SWB will affect health and when interventions to increase SWB will improve health.

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REFERENCES

- Ben-Shaanan, T.L., Azulay-Debby, H., Dubovik, T., Starovetsky, E., Korin, B., Schiller, M., et al. (2016). Activation of the reward system boosts innate and adaptive immunity. *Nature Medicine*, 22, 940–944.

- Binder, M., & Coad, A. (2013). Life satisfaction and self-employment: A matching approach. *Small Business Economics*, *40*, 1009–1033. <https://doi.org/10.1007/s11187-011-9413-9>
- Black, P.H., & Garbutt, L.D. (2002). Stress, inflammation and cardiovascular disease. *Journal of Psychosomatic Research*, *52*, 1–23. [https://doi.org/10.1016/S0022-3999\(01\)00302-6](https://doi.org/10.1016/S0022-3999(01)00302-6)
- Broadbent, E., Kahokehr, A., Booth, R., Thomas, J., Windsor, J.A., Buchanan, C.M., et al. (2012). A brief relaxation intervention reduces stress and improves surgical wound healing response: A randomised trial. *Brain, Behavior, and Immunity*, *26*, 212–217. <https://doi.org/10.1016/j.bbi.2011.06.014>
- Brummett, B.H., Boyle, S.H., Kuhn, C.M., Siegler, I.C., & Williams, R.B. (2009). Positive affect is associated with cardiovascular reactivity, norepinephrine level, and morning rise in salivary cortisol. *Psychophysiology*, *46*, 862–869.
- Buchanan, T.W., al'Absi, M., & Lovallo, W.R. (1999). Cortisol fluctuates with increases and decreases in negative affect. *Psychoneuroendocrinology*, *24*, 227–241.
- Cohen, S., Alper, C.M., Doyle, W.J., Treanor, J.J., & Turner, R.B. (2006). Positive emotional style predicts resistance to illness after experimental exposures to rhinovirus or influenza A virus. *Psychosomatic Medicine*, *68*, 809–815.
- Curhan, K.B., Sims, T., Markus, H.R., Kitayama, S., Karasawa, M., Kawakami, N., et al. (2014). Just how bad negative affect is for your health depends on culture. *Psychological Science*, *25*(12), 2277–2280. <https://doi.org/10.1177/0956797614543802>
- Danner, D.D., Snowdon, D.A., & Friesen, W.V. (2001). Positive emotions in early life and longevity: Findings from the nun study. *Journal of Personality and Social Psychology*, *80*, 804–813.
- Diener, E., Oishi, S., & Lucas, R.E. (2017). Advances and open questions in the science of subjective well-being. In preparation, University of Virginia and University of Utah.
- Diener, E., Wirtz, D., Tov, W., Kim-Prieto, C., Choi, D.W., Oishi, S., et al. (2010). New well-being measures: Short scales to assess flourishing and positive and negative feelings. *Social Indicators Research*, *97*, 143–156.
- Drury, S.S., Mabile, E., Brett, Z.H., Esteves, K., Jones, E., Shirtcliff, E.A., et al. (2014). The association of telomere length with family violence and disruption. *Pediatrics*, *134*, e128–e137.
- Dubois, C.M., Lopez, O.V., Beale, E.E., Healy, B.C., Boehm, J.K., & Huffman, J.C. (2015). Relationships between positive psychological constructs and health outcomes in patients with cardiovascular disease: A systematic review. *International Journal of Cardiology*, *195*, 265–280.
- Epel, E.S., Blackburn, E.H., Dhabhar, F.S., Adler, N.E., Morrow, J.D., & Cawthon, R.M. (2004). Accelerated telomere shortening in response to life stress. *Proceedings of the National Academy of Sciences, USA*, *101*(49), 17312–17315. <https://doi.org/10.1073/pnas.0407162101>
- Fredrickson, B.L., Mancuso, R.A., Branigan, C., & Tugade, M.M. (2000). The undoing effect of positive emotions. *Motivation and Emotion*, *24*(4), 237–258.

- Friedman, E.M., Ruini, C., Foy, R., Jaros, L.V., Sampson, H., & Ryff, C.D. (2017). Lighten UP! A community-based group intervention to promote psychological well-being in older adults. *Aging & Mental Health, 21*(2), 199–205.
- Fujita, F., & Diener, E. (2005). Life satisfaction set-point: Stability and change. *Journal of Personality and Social Psychology, 88*, 158–164.
- Graham, C., Higuera Jaramillo, L., & Lora, E. (2011). Which health conditions cause the most unhappiness? *Health Economics, 20*(12), 1431–1447. <http://EconPapers.repec.org/RePEc:wly:hlthec:v:20:y:2011:i:12:p:1431-1447>
- Gunaratne, P., Lloyd, A.R., & Vollmer-Conna, U. (2013). Mood disturbance after infection. *Australian & New Zealand Journal of Psychiatry, 47*, 1152–1164. <https://doi.org/10.1177/0004867413503718>
- Harding, E.J., Paul, E.S., & Mendl, M. (2004). Animal behaviour: Cognitive bias and affective state. *Nature, 427*, 312. <https://doi.org/10.1038/427312a>
- Henry, J.P., & Stephens-Larson, P. (1985). Specific effects of stress on disease processes. In G.P. Moberg (Ed.), *Animal stress* (pp. 161–175). New York: Springer Publishing.
- Hoen, P.W., Denollet, J., de Jong, P., & Whooley, M.A. (2013). Positive affect and survival in patients with stable coronary heart disease: Findings from the Heart and Soul study. *Journal of Clinical Psychiatry, 74*, 716–722.
- Howell, R.T., Kern, M.L., & Lyubomirsky, S. (2007). Health benefits: Meta-analytically determining the impact of well-being on objective health outcomes. *Health Psychology Review, 1*, 83–136. <https://doi.org/10.1080/17437190701492486>
- Hubbard, R.E., Goodwin, V.A., Llewellyn, D.J., Warmoth, K., & Lang, I.A. (2014). Frailty, financial resources and subjective well-being in later life. *Archives of Gerontology and Geriatrics, 58*, 364–369. <https://doi.org/10.1016/j.archger.2013.12.008>
- Imbens, G.W., & Rubin, D.B. (2015). *Causal inference for statistics, social, and biomedical sciences*. New York: Cambridge University Press.
- Janicki-Deverts, D., Cohen, S., Doyle, W.J., Turner, R.B., & Treanor, J.J. (2007). Infection-induced proinflammatory cytokines are associated with decreases in positive affect, but not increases in negative affect. *Brain, Behavior, and Immunity, 21*, 301–307.
- Jacobs, T.L., Epel, E.S., Lin, J., Blackburn, E.H., Wolkowitz, O.M., Bridwell, D.A., et al. (2011). Intensive meditation training, immune cell telomerase activity, and psychological mediators. *Psychoneuroendocrinology, 36*, 664–681. <https://doi.org/10.1016/j.psyneuen.2010.09.010>
- Joseph, D., Chan, M., Heintzelman, S., Tay, L., & Diener, E. (2017). The experimental manipulation of mood: A meta-analysis of mood induction procedures. Manuscript submitted for publication.
- Kahneman, D. (1965). Control of spurious association and the reliability of the controlled variable. *Psychological Bulletin, 64*, 326–329.
- Kiecolt-Glaser, J.K., Loving, T.J., Stowell, J.R., Malarkey, W.B., Lemeshow, S., Dickinson, S.L., et al. (2005). Hostile marital interactions, proinflammatory cytokine production, and wound healing. *Archives of General Psychiatry, 62*, 1377–1384.
- Kiecolt-Glaser, J.K., Marucha, P.T., Malarkey, W.B., Mercado, A.M., & Glaser, R. (1995). Slowing of wound healing by psychological stress. *Lancet, 346*, 1194–1196.

- Kirschbaum, C., Pirke, K.M., & Hellhammer, D.H. (1993). The “Trier Social Stress Test”: A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, 28, 76–81.
- Kitayama, S., Park, J., Morozink Boylan, J., Miyamoto, Y., & Levine, C.S. (2015). Expression of anger and ill health in two cultures: An examination of inflammation and cardiovascular risk. *Psychological Science*, 26(2), 211–220.
- Kopp, M., Bonatti, H., Haller, C., Rumpold, G., Söllner, W., Holzner, B., et al. (2003). Life satisfaction and active coping style are important predictors of recovery from surgery. *Journal of Psychosomatic Research*, 55, 371–377.
- Kroenke, C.H., Seeman, T., Matthews, K., Adler, N., & Epel, E. (2012). Mood patterns based on momentary assessment of positive and negative moods over a day and coronary artery calcification in the CARDIA study. *Psychosomatic Medicine*, 74, 526–534. <https://doi.org/10.1097/PSY.0b013e3182583e68>
- Kushlev, K., Heintzelman, S.J., Lutes, L.D., Wirtz, D., Oishi, S., & Diener, E. (2017). ENHANCE: Design and rationale of a randomized controlled trial for promoting enduring happiness and well-being. *Contemporary Clinical Trials*, 52, 62–74.
- Liu, B., Floud, S., Pirie, K., Green, J., Peto, R., & Beral, V. (2016). Does happiness itself directly affect mortality? The prospective UK Million Women Study. *The Lancet*, 387 (10021), 874–881. [https://doi.org/10.1016/S0140-6736\(15\)01087-9](https://doi.org/10.1016/S0140-6736(15)01087-9)
- Lyubomirsky, S., King, L., & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin*, 131, 803–855. <https://doi.org/10.1037/0033-2909.131.6.803>
- Marchant-Forde, J.N. (2015). The science of animal behavior and welfare: Challenges, opportunities, and global perspective. *Frontiers in Veterinary Science*, 2, 16. <https://doi.org/10.3389/fvets.2015.00016>
- Marucha, P.T., Kiecolt-Glaser, J.K., & Favagehi, M. (1998). Mucosal wound healing is impaired by examination stress. *Psychosomatic Medicine*, 60, 362–365.
- Mayer, A., Thoemmes, F., Rose, N., Steyer, R., & West, S.G. (2014). Theory and analysis of total, direct, and indirect causal effects. *Multivariate Behavioral Research*, 49, 425–442.
- Meehl, P.E. (1970). Nuisance variables and the ex post facto design. In M. Radner & S. Winokur (Eds.), *Minnesota studies in the philosophy of science: Vol. IV. Analyses of theories and methods of physics and psychology* (pp. 373–402). Minneapolis, MN: University of Minnesota Press.
- Mitchell, C., Hobcraft, J., McLanahan, S.S., Siegel, S.R., Berg, A., Brooks-Gunn, J., et al. (2014). Social disadvantage, genetic sensitivity, and children’s telomere length. *Proceedings of the National Academy of Sciences, USA*, 111, 5944–5949.
- Miyamoto, Y., Boylan, J.M., Coe, C.L., Curhan, K.B., Levine, C.S., Markus, H.R., et al. (2013). Negative emotions predict elevated interleukin-6 in the United States but not in Japan. *Brain, Behavior, and Immunity*, 34, 79–85. <https://doi.org/10.1016/j.bbi.2013.07.173>
- Moberg, G.P. (1985). Influence of stress on reproduction: Measure of well-being. In G.P. Moberg (Ed.), *Animal stress* (pp. 245–267). New York: Springer.
- Moskowitz, J.T., Hult, J.R., & Duncan, L.G. (2012). A positive affect intervention for people experiencing health-related stress: Development and non-randomized pilot test. *Journal of Health Psychology*, 17(5), 676–692.

- Mukuria, C., & Brazier, J. (2013). Valuing the EQ-5D and the SF-6D health states using subjective well-being: A secondary analysis of patient data. *Social Science & Medicine*, *77*, 97–105.
- Ong, A.D. (2010). Pathways linking positive emotion and health in later life. *Current Directions in Psychological Science*, *19*, 358–362. <https://doi.org/10.1177/0963721410388805>
- Parks, A., & Biswas-Diener, R. (2013). Positive interventions: Past, present, and future. In T. Kashdan & J. Ciarrochi (Eds.), *Bridging acceptance and commitment therapy and positive psychology: A practitioner's guide to a unifying framework* (pp. 140–165). Oakland, CA: New Harbinger.
- Powell, N.D., Sloan, E.K., Bailey, M.T., Arevalo, J.M., Miller, G.E., Chen, E., et al. (2013). Social stress up-regulates inflammatory gene expression in the leukocyte transcriptome via B-adrenergic induction of myelopoiesis. *Proceedings of the National Academy of Sciences, USA*, *41*, 16574–16579.
- Pressman, S.D., & Cohen, S. (2005). Does positive affect influence health? *Psychological Bulletin*, *131*, 925–971.
- Proyer, R.T., Gander, F., Wellenzohn, S., & Ruch, W. (2014). Positive psychology interventions in people aged 50–79 years: Long-term effects of placebo-controlled online interventions on well-being and depression. *Aging & Mental Health*, *18*(8), 997–1005.
- Robles, T.F., Brooks, K.P., & Pressman, S.D. (2009). Trait positive affect buffers the effects of acute stress on skin barrier recovery. *Health Psychology*, *28*, 373–378.
- Rohrer, J. (2017). What's an age-effect net of all time-varying covariates? [Blog Post]. Retrieved from: <http://www.the100.ci/author/julia/>
- Sadler, M.E., Miller, C.J., Christensen, K., & McGue, M. (2011). Subjective well-being and longevity: A co-twin control study. *Twin Research and Human Genetics: The Official Journal of the International Society for Twin Studies*, *14*, 249–256. <https://doi.org/10.1375/twin.14.3.249>
- Sapolsky, R. M. (Ed.) (1994). *Why zebras don't get ulcers: A guide to stress, stress-related diseases, and coping*. Stanford, CA: Stanford Alumni Association.
- Segerstrom, S.C. (2014). Affect and self-rated health: A dynamic approach with older adults. *Health Psychology*, *33*, 720–728.
- Seligman, M.E.P., Steen, T.A., Park, N., & Peterson, C. (2005). Positive psychology progress: Empirical validation of interventions. *American Psychologist*, *60*(5), 410–421.
- Shirom, A., Toker, S., Jacobson, O., & Balicer, R.D. (2010). Feeling vigorous and the risks of all-cause mortality, ischemic heart disease, and diabetes: A 20-year follow-up of healthy employees. *Psychosomatic Medicine*, *72*, 727–733. <https://doi.org/10.1097/PSY.0b013e3181eeb643>
- Sin, N.L., & Lyubomirsky, S. (2009). Enhancing well-being and alleviating depressive symptoms with positive psychology interventions: A practice-friendly meta-analysis. *Journal of Clinical Psychology*, *65*(5), 467–487.
- Skaff, M.M., Mullan, J.T., Almeida, D.M., Hoffman, L., Masharani, U., Mohr, D., et al. (2009). Daily negative mood affects fasting glucose in type 2 diabetes. *Health Psychology*, *28*, 265–272. <https://doi.org/10.1037/a0014429>
- Spector, P.E., Zapf, D., Chen, P.Y., & Frese, M. (2000). Why negative affectivity should not be controlled in job stress research: Don't throw out the baby with the bath water. *Journal of Organizational Behavior*, *21*, 79–95.

- Step toe, A. (2016, 2 December). Subjective well-being and health: Understanding the mechanisms. Symposium on the Science of Health and Happiness. Harvard T. H. Chan School of Public Health. Cambridge, MA.
- Step toe, A., Gibson, E.L., Hamer, M., & Wardle, J. (2007). Neuroendocrine and cardiovascular correlates of positive affect measured by ecological momentary assessment and by questionnaire. *Psychoneuroendocrinology*, *32*, 56–64.
- Step toe, A., O'Donnell, K., Badrick, E., Kumari, M., & Marmot, M. (2008). Neuroendocrine and inflammatory factors associated with positive affect in healthy men and women: Whitehall II study. *American Journal of Epidemiology*, *167*, 96–102.
- Strike, P.C., Wardle, J., & Step toe, A. (2004). Mild acute inflammatory stimulation induces transient negative mood. *Journal of Psychosomatic Research*, *57*, 189–194.
- Vitalo, A., Fricchione, J., Casali, M., Berdichevsky, Y., Hoge, E.A., Rauch, S.L., et al. (2009). Nest making and oxytocin comparably promote wound healing in isolation reared rats. *PLoS ONE*, *4*, e5523. <https://doi.org/10.1371/journal.pone.0005523>
- Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS Scales. *Journal of Personality and Social Psychology*, *54*, 1063–1070.
- Weiss, A., Adams, M.J., & King, J.E. (2011). Happy orangutans live longer lives. *Biology Letters*, *23*, 872–874.
- Westfall, J., & Yarkoni, T. (2016). Statistically controlling for confounding constructs is harder than you think. *PLoS ONE*, *11*(3), 0152719. <https://doi.org/doi.org/10.1371/journal.pone.0152719>
- Wikman, A., Wardle, J., & Step toe, A. (2011). Quality of life and affective well-being in middle-aged and older people with chronic medical illnesses: A cross-sectional population based study. *PLoS One*, *6*(4), e18952.
- Wright, C.E., Strike, P.C., Brydon, L., & Step toe, A. (2005). Acute inflammation and negative mood: Mediation by cytokine activation. *Brain, Behavior, and Immunity*, *19*(4), 345–350.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix S1: Tables 1 – 9 and Supporting References