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Positive Affect and Health: What Do We Know and Where Next Should We Go?

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Abstract

Positive affect (PA) is associated with better health across a wide range of physical health outcomes. This review reflects on why the study of PA is an essential component of our understanding of physical health and expands on pathways that connect these two variables. To encourage forward movement in this burgeoning research area, measurement and design issues in the study of PA and health are discussed, as are the connections between PA and a range of different health outcomes. Plausible biological, social, and behavioral pathways that allow for positive feelings to get under the skin and influence physical wellness are detailed and framed in the context of several theoretical models. Finally, new directions for the field and important methodological and interpretative considerations that are essential to moving this important research area forward are explored.

Contents

INTRODUCTION

Humans have a strong desire to be both healthy and happy. This public want is echoed by advertising campaigns focused on being at the "corner of happy and healthy" (Walgreens™) and best-selling book lists consistently featuring literature on these topics. Recently, there has also been a surge of research tackling these two topics, including studies testing the complex interconnections between these variables. The 14-year-old seminal review of research in this area (Pressman & Cohen 2005) included approximately 70 studies of health outcomes like mortality, disease morbidity, disease severity, survival after disease diagnosis, and pain, as well as over 100 studies on physiological outcomes. Since then, the literature has grown tremendously, including the addition of many important conceptual replications of early work.

Several more recent qualitative and quantitative reviews have similarly indicated that positive affect (PA) is associated with health benefits such as a longer life (Chida & Steptoe 2008, Diener & Chan 2011, Zhang & Han 2016), cardiovascular health (Boehm & Kubzansky 2012), and better outcomes in chronic diseases like cancer and HIV (Hernandez et al. 2018). Taken together, there is now impressive evidence that PA short-term states and long-lasting traits have extensive correlations with an array of health and health-relevant outcomes. Furthermore, prospective longitudinal studies of health and experimental lab affect manipulations examining physiological change outcomes hint at causal effects of PA on health. However, many questions remain. For example, what underlies inconsistencies in the literature? What are the mechanisms connecting PA and health? And, importantly, can PA interventions improve health? The goal of this review is to delve into these issues, with a focus on important study characteristics and theories that help

unpack these questions. A final objective is to help researchers design and interpret their work in a way that will deepen the literature and propel the field forward.

Due to the wide array of assessment approaches in this field, it is critical to first discuss central measurement issues, both for PA and for health, and then provide a broad overview of recent evidence connecting these variables. Next, theories that indicate how PA can get under the skin to influence health are explored alongside evidence supporting the hypothesized pathways. The burgeoning literature examining PA-increasing interventions that aim to maintain or improve physical health is also described and evaluated. Finally, the most pressing new directions for the field of PA and health are outlined to demonstrate important ways to fill gaps in the literature.

MEASUREMENT CONSIDERATIONS

Positive Affect

PA is generally described as the experience of pleasurable emotions, such as happiness, joy, excitement, enthusiasm, calm, and contentment. PA measures vary in their inclusion of different affective words and their assessed time frames (i.e., the duration of affect). Thus, measurement considerations like these are discussed below, along with important issues that arise depending on the approach taken.

Time frame. One surprisingly ignored topic when selecting a measure in PA and health studies is the time period over which participants are asked to report their experiences of PA. Self-reported PA assessments begin with an interval to evaluate, such as the current moment (i.e., emotion or state affect), the past week (i.e., positive mood), or in general (i.e., trait affect). There is abundant evidence that state affect can alter in-the-moment physiological factors like cardiovascular, immune, and endocrine outcomes, as well as health behaviors (see section titled The Main Effect Model of Positive Affect and Health). Thus, for brief experimental and diary studies on health-relevant mechanisms, state PA is the appropriate measurement choice. In contrast, in terms of distant outcomes (e.g., mortality), trait affect has ample opportunity to repeatedly influence factors like behavior, physiology, and social relationships over time, making it the logical measurement choice. It is not uncommon, however, for researchers to ask questions about state affect (e.g., a single day's happiness) and then connect it to outcomes assessed years later (e.g., mortality) (Steptoe & Wardle 2011). Although, from a mechanistic standpoint, it would be unexpected that feeling positive on a single day might foretell health decades later, short-term assessments do sometimes predict distant outcomes. This is likely due to their statistical, albeit noisy, overlap with trait affect. Thus, prior to choosing an affect assessment, researchers need to carefully consider whether state or trait is the best match for the timing of PA's association with the health outcome. This consideration also casts a different light on a common practice of contrasting trait eudaimonia (e.g., life meaning, purpose) assessments against state PA assessments (i.e., hedonia) with the intent of arguing that one matters more than the other in the context of health (e.g., Friedman et al. 2017). Based on the explanation above, longer-lasting measures of trait positivity (e.g., life purpose or satisfaction) should (and do) consistently outperform measures of transient state affect in predicting health outcomes. While it is a critical step in this field to determine which types of affective constructs matter for different outcomes, a more constructive future approach would be to contrast equivalent time assessments.

Number and content of items. PA is typically measured using adjective rating scales with terms representing specific affective experiences (e.g., happy, excited, calm, etc.). Participants rate how

much each adjective represents how they currently feel or felt over a certain time frame. Since there are many affectively oriented scales to choose from, a careful choice is warranted. Selection of a measurement tool should be guided by underlying conceptual models and a thoughtful exploration of what the best choice might be. What is more common is an atheoretical approach constrained by what has been used before or what is available in an existing data set. For example, the 20-item Center for Epidemiological Studies-Depression (CES-D) scale (Radloff 1977) is repeatedly employed in PA and health research not because it is an ideal assessment of PA, but because it has been frequently included in large medical data sets and has a four-item positive subscale. This positive subscale combines affect (happiness) and nonaffect (life enjoyment, hope, and self-esteem) items, complicating the interpretation of the results. Similarly, many studies utilize single-item PA assessments (e.g., Liu et al. 2016) such as "How often do you feel happy?" While time efficient, one item cannot capture all of PA and may therefore result in missing or weak effects of PA on assessed outcomes.

When possible, it is best to use well-designed and validated affect assessments. For example, the 20-item Positive and Negative Affect Schedule (PANAS; Watson et al. 1988) is frequently selected because it has the desirable feature that PA and negative affect (NA) are statistically separable. This is important given the frequently asked question of whether PA effects are simply due to a lack of NA. Separability of constructs allows for simultaneous assessment in analyses. While the PANAS is an excellent measure in terms of psychometric properties, what many researchers do not consider is that the underlying theoretical orientation of this measure assumes that PA is pleasure and high arousal (e.g., alert, excited). Thus, if a researcher is interested in calm or happiness, the PANAS is inappropriate. Instead, a dimensional model (e.g., Russell 1980) where PA and arousal are separable (e.g., into high, mid, and low arousal) (Cohen et al. 2003, Usala & Hertzog 1989) is more suitable. This is especially important given evidence that arousal types are distinctly associated with health outcomes. For example, a growing body of work shows that it is the higher-arousal components of PA that are most tied to lower risk of death (Petrie et al. 2018, Pressman & Cohen 2012) and disease (Shirom et al. 2010). While calm has only rarely been associated with health and physiology (for an exception concerning blood lipids, see Shirom et al. 2009), this may be due to a lack of attention to cultural norms that prioritize different arousal levels of PA (e.g., Sims & Carstensen 2014). Needless to say, researchers should make an informed decision about what measure is most suitable for their study design and objectives and consider the examination of subtypes of affect. When there is no ability to choose a measure a priori, researchers can consider breaking down larger constructs into single items (e.g., discrete emotions) to explore active subingredients. Finally, researchers should not assume interchangeability of PA measures and clearly acknowledge limitations of the measure that they use.

Non-self-report assessments of positive affect. Many have advocated for the use of multiple or alternative methods beyond self-report in affective science due to issues such as self-presentation bias or differences in response styles. One example of the use of an alternative method is seen in studies that examine affectively laden language use. Utilizing this method, researchers have found that higher numbers of high-arousal PA words in the autobiographies of well-known psychologists were associated with longer author life (Pressman & Cohen 2012), and that positive Twitter language correlates with lower cardiovascular disease at the county level (Eichstaedt et al. 2015). While emotional language use is clearly something different than emotion self-report (Pennebaker et al. 2003), it helps provide a complementary source of evidence by removing many forms of reporting bias, since participants rarely know what is being studied or even that they are being studied.

Measurement of smiling, especially Duchenne smiling (expression that activates both orbicularis oculi muscles around the eyes and zygomaticus major muscles in the cheeks), is another alternative method to measure PA. Duchenne smiling is positively correlated with self-reports of PA and is tied to neurological changes consistent with PA (Ekman & Davidson 1993). Smiles are rarely studied in the context of health; however, studies have found that covert manipulations (Kraft & Pressman 2012) and naturally occurring smiles (Fredrickson & Levenson 1998) predict better cardiovascular recovery following stress, a health-relevant outcome. Additionally, naturally occurring smiles during structured interviews (among other PA indicators) were associated with a 22% decreased risk of heart disease over a 10-year follow-up period (Davidson et al. 2010). Smiling in professional baseball player cards was not correlated with players' mortality in a recent study (Dufner et al. 2017), indicating a need to consider the source and meaning of smiles, since it is likely that photographs for public consumption may represent something different (e.g., self-presentation preferences, agreeableness) than lab-based, experimentally manipulated, and naturally occurring smiles. Despite their limitations, these approaches are novel and provide convergent validity for self-reported affect findings, as well as suggest plausible unique pathways to health [e.g., via differences in expression versus suppression, health behaviors, or even direct nerve stimulation to peripheral physiology via muscle changes in facial expression (Cross & Pressman 2018, Pressman & Cross 2018)]. Thus, we advocate for these and other novel approaches to PA assessment (e.g., behavioral coding, observer reports, neural and physiological indicators) in addition to self-report approaches.

Physical Health

While the World Health Organization (**http://www.who.int/about/mission/en/**) describes health as something more than the absence of disease or infirmity, there is no single objective biological measure of health, so researchers rely on mortality, disease, and disease-relevant outcomes. Changes in physiology, while health relevant, are rarely at a magnitude that would have health-altering impacts in the moment. Thus, a change in cortisol or immune activity during an emotion induction should not be considered a physical health outcome, but rather a possible pathway to health.

One of the more pressing issues to consider is the item overlap between measures of health and measures of PA, which can artificially inflate the statistical associations between PA and health. Specifically, some measures of self-reported health utilize words like vigor, activity, and energy to assess wellness (e.g., SF-36; Ware & Sherbourne 1992). These same items are used in many popular PA scales [e.g., the Profile of Mood States (McNair et al. 1971), the PANAS (Watson et al. 1988)]. As a result, it is critical for researchers to carefully covary measures of objective or perceived health at baseline, especially when assessing high-arousal PA, which is more likely to reflect feelings of physical wellness.

REVIEW OF POSITIVE AFFECT AND HEALTH

In this section, we provide a brief assessment of the recent literature on PA and specific health outcomes, with a focus on research from the past 15 years. Examples are drawn from high-quality studies that account for critical factors in the study of PA and health, including adjusting for baseline health, health-relevant behaviors (e.g., smoking, exercise), disease-relevant factors (e.g., medications, markers of disease progression), and NA or a similar negativity measure. Generally, recent studies have been consistent in considering these covariates, and PA results regularly withstand adjustment for NA and other factors (for a meta-analysis, see Chida & Steptoe 2008).

Mortality

Longitudinal studies of PA that examine length of life in healthy populations are the most common type of study in this field (for reviews of this literature and examples of studies, see Chida & Steptoe 2008, Diener & Chan 2011). Pressman & Cohen's (2005) review noted reliable PA benefits in healthy older adults in approximately a dozen studies, but less consistency in middle-aged and young populations. This PA benefit for older individuals is echoed in a recent meta-analysis (Zhang & Han 2016) that revealed a lower risk of mortality for those with high PA over age 55. There may be reasons to believe that PA matters more in the later parts of life than earlier, when other factors less related to PA are more closely predictive of death. For example, chronic illnesses are less likely to kill in early to midlife than are factors such as unintentional injuries and homicides (Murphy et al. 2017) that may have nothing to do with PA. This type of issue may explain some inconsistencies in the results for younger and middle-aged groups (e.g., Liu et al. 2016). Related to the discussion above of arousal level, high-arousal PA seems to be driving many of the PA-related mortality effects in studies explicitly looking at this relationship (Petrie et al. 2018, Pressman & Cohen 2012), raising the question of what it is about feeling excited and vigorous that is healthful.

Morbidity

Like studies of mortality, morbidity research is primarily focused on measuring healthy populations at baseline and then following them prospectively over time. In the case of morbidity research, the question to be answered is whether PA is associated with future disease onset or incidence of injury. Although the diversity of morbidity outcomes (e.g., cardiovascular diseases, infection, physical decline) is impressive, the main limitation in studying them is a low replication rate within any one outcome type. The most-studied outcomes in this category are cardiovascular outcomes. Specifically, there is extensive research in large, well-controlled epidemiological studies testing associations between self-reported PA and heart disease (for a review, see Boehm & Kubzansky 2012). While there are a number of positive findings, including PA effects on outcomes like reduced stroke (Ostir et al. 2001) and decreased hospital readmission following cardiovascular issues (Middleton & Byrd 1996), not all recent data are consistent. This is especially true for studies using measures of PA that include a wide range of nonaffect well-being items (e.g., optimism, confidence, life evaluations) via the CES-D and other similar measures (Freak-Poli et al. 2015). These mixed results point to a need for further replication and dissection of which specific types of PA impact different cardiovascular-relevant outcomes and when.

Beyond cardiovascular disease, some of the best evidence for PA's morbidity effects comes from the well-designed experimental cold and flu study paradigms. Typically, infectious illness studies are confounded by uncontrollable exposure-related issues. However, using this methodology, all participants are exposed to a novel upper respiratory virus in isolation. Infection incidence is also assessed by objective indicators (e.g., mucus production, viral replication). In these studies, lower levels of state PA (over two weeks prior to exposure) have been associated with more objective and subjective signs of illness (Doyle et al. 2006). Furthermore, higher PA predicted resistance to both flu and cold, even after accounting for an array of related positive (e.g., optimism, extraversion, esteem, purpose), negative (e.g., NA), demographic, and health variables, a result that replicated similar past work (Cohen et al. 2003).

There is evidence that PA is also predictive of future injury and the incidence of physical decline (i.e., slowed walking speed, decreased strength). For example, in two studies of older adults, higher PA (measured with the CES-D positive subscale) was associated with a reduced risk of frailty over a few years of follow-up (Park-Lee et al. 2009). Higher PA has also been associated with slower

functional decline (e.g., inability to walk, self-feed, and bathe) (Hirosaki et al. 2013) and lower likelihood of the development of a new disability (Díaz-Ramos et al. 2012) in older adults. These results complement past work on younger samples tying PA and life satisfaction to a reduced risk of injury (Koivumaa-Honkanen et al. 2000, Smith et al. 1997); this growing literature shows that PA is connected with better physical function across ages and domains.

Disease Severity, Progression, and Survival in People with Chronic Illness

Past reviews on this literature found that the evidence for PA benefits in those who were already ill was mixed, especially for survival, and little replication had been done at the disease level. The pattern seemed to indicate that individuals with early stage disease were better helped by PA than those at later stages (for discussion, see Pressman & Cohen 2005), possibly because the mechanisms (e.g., reduced stress, healthy behaviors) connecting PA to health have more potential for impact before, for example, organs are failing and millions of cancer cells have replicated. This possibility is supported by a meta-analysis showing a very small effect of positive well-being on mortality in those with illness (HR = 0.98; CI [.95,1.00]; $p = 0.03$) (Chida & Steptoe 2008). To date, the literature has discussed several mechanistic reasons by which most of the diseases described below could benefit from PA, and growing evidence to this effect is described in the section titled Models of Positive Affect and Health.

Cardiovascular disease. While not exclusively focused on PA, a recent systematic review revealed that many well-being constructs, including PA, are positively associated with lower cardiovascular disease severity (e.g., fewer cardiac events and rehospitalizations) and increased survival in patients with cardiovascular disease (Dubois et al. 2015), echoing the morbidity findings discussed above. Dubois et al. (2015) reviewed six studies that examined associations between PA and survival. Benefits were found in studies using mid to high arousal scales (i.e., PANAS and a happiness scale) (Grunberg et al. 2003, Hoen et al. 2013), as opposed to studies using less pure assessments of PA, like the Global Mood Scale (GMS) (Denollet 1993), which found fewer benefits. In one study, the GMS, which includes high-arousal PA in addition to feelings of industry, sociability, and esteem, did predict survival. This effect was lost, however, after accounting for covariates including physical activity, which was hypothesized to be a possible mediator of the survival effect (Hoogwegt et al. 2013). Evidence has also been found that PA predicts reduced cardiac events, even after adjusting for factors like disease severity and depression (e.g., Hoen et al. 2013, Hoogwegt et al. 2013). While high-arousal PA seems to be helpful, given the potential negative effects of arousal on individuals with heart conditions, researchers will need to be wary of possible U-shaped associations in future studies (Armon et al. 2014). Despite mounting evidence that PA is related to better health outcomes in cardiovascular disease, it is clear that more work needs to be done to determine the types of PA that are most helpful in this context.

Diabetes. While a relatively new area of study, PA has also been tied to better survival in individuals with diabetes (Moskowitz et al. 2008). Of interest when considering what drives this association, the item "I enjoyed life" in the CES-D PA subscale was the most strongly predictive item of survival. Similarly, low PA (low scores on the items "I have looked forward with enjoyment to things" and "I have been able to laugh and see the funny side of things" from the Edinburgh Postnatal Depression Scale) was associated with an almost twofold increased risk of dying in patients with type 2 diabetes (Nefs et al. 2016). This is in line with studies associating higher PA with better glycemic control (Nefs et al. 2012), suggesting one likely mechanistic pathway of PA's impact on diabetes-relevant outcomes.

HIV. In patients diagnosed with HIV, positive feelings like compassionate love (Ironson et al. 2018) and other PA and PA-relevant measures (e.g., meaning, altruism) predict slower disease progression (Ironson & Hayward 2008), a higher likelihood of achieving suppressed viral load (i.e., the treatment goal) (Wilson et al. 2017), and higher survival (Moskowitz 2003). For example, a recently published longitudinal study indicated that PA assessed with the CES-D subscale was associated with a higher likelihood of subsequent viral load suppression in women with HIV (Wilson et al. 2017). While these results are promising, because of the mix of PA-relevant constructs in this literature, it may be that a host of positive factors are helpful in managing a serious and multifaceted illness like HIV.

Cancer. Surprisingly, there are few published studies of PA and recurrence of cancer, progression of cancer, or mortality among people with cancer. In a recent study of patients with metastatic renal cell carcinoma (Prinsloo et al. 2015), participant scores on the PA subscale of the CES-D predicted longer survival. Notably, survival was better for patients who had both high PA and low depressive symptoms, supporting the importance of looking at both valences together. This literature is still small and mixed (for a review of past examples, see Pressman & Cohen 2005), and many studies have been focused on understanding predictors of PA in cancer patients (e.g., Costanzo et al. 2009) rather than on PA predicting cancer. That being said, there is extensive evidence that stress-related psychosocial factors predict cancer incidence and poorer survival, with stressful events in particular playing an important role in survival (Chida et al. 2008). Given the stress-altering effects of PA (discussed below), there are many reasons to predict that PA could play an important role at multiple stages of disease.

Self-Reported Symptoms and Pain

PA has been consistently associated with reduced symptoms and pain ratings in both unhealthy and healthy samples. Recent studies have revealed that individuals who report higher PA report less pain in chronic pain conditions (Strand et al. 2007, Zautra et al. 2005), fewer symptoms during acute illness (Cohen et al. 2006, Doyle et al. 2006), and reduced pain months after being discharged from a hospital (Berges et al. 2011). Furthermore, benefits are also found in healthy samples (Kelsey et al. 2006). While this literature is relatively consistent, there are some exceptions. For example, spinal surgery patients did not show a benefit of high-arousal PA on pain months following surgery (Seebach et al. 2012), although PA did aid in physical function. Similarly, answers on the high-arousal GMS were not associated with postangioplasty pain months later, although, again, it was associated with better activity (e.g., self-care) (Versteeg et al. 2009). This hints at the important possibility that high-arousal PA, in particular, may not be beneficial for pain but is tied to physical function. Also of note is that there is some limit to examining self-reported data, such as symptoms and pain, in the context of PA, given that there is no way of knowing if the effect is biological or perceptual. This is in addition to the problem of covariation between these variables based on the method of data collection (i.e., self-report) that could result in problems due to self-presentation effects or other unintentional biases in reporting emotions and sensations.

MODELS OF POSITIVE AFFECT AND HEALTH

It is evident that there are many connections between PA and health. The natural question that then arises is how these connections are occurring. Researchers have hypothesized a number of plausible pathways that they are only just starting to investigate. Like the issues of measurement

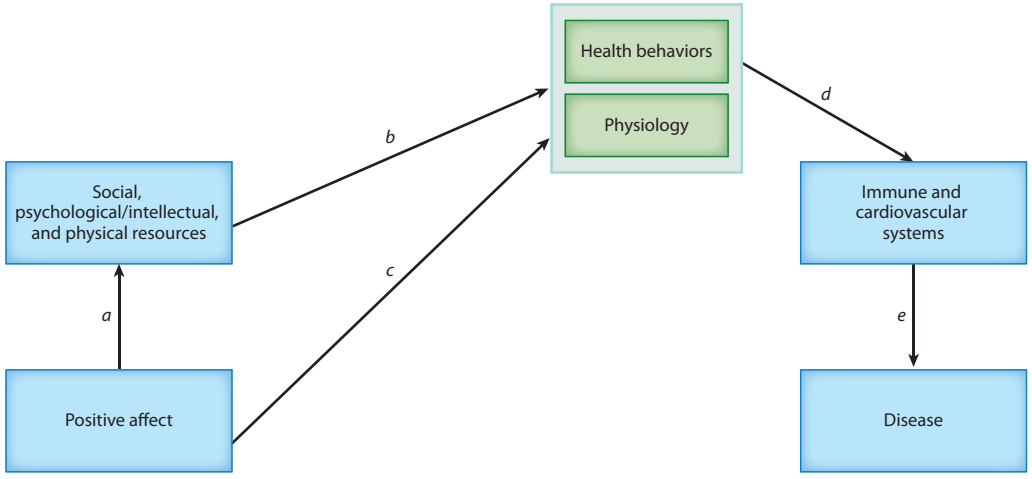

Figure 1

Main effect model of positive affect (PA). This figure illustrates the mediating effects of resources (social, psychological/intellectual, and physical), health behaviors (e.g., sleep, diet, exercise), and physiology (e.g., hormones, microbiome, epigenetics, neurotransmitters, opioids) between PA and disease. An absence of a line does not indicate that an association between variables does not occur, nor do arrows indicate a single direction of causality. Rather, lines drawn represent the focus of this model, and arrows go in only one direction for simplicity.

discussed above, it is essential for researchers to carefully consider theoretical, design, and statistical approaches to unraveling the likely complex mechanisms linking PA and health. Two promising models connected to this literature and evidence supporting them are reviewed in the following sections.

The Main Effect Model of Positive Affect and Health

The main effect model of PA and health (Pressman & Cohen 2005) is the common default model that researchers operate under when doing work in this area. It proposes that PA has main effects on health through pathways such as positive health behaviors; protective or health-relevant physiological changes; and social, psychological/intellectual, and physical resources.

Mediation. As shown in **Figure 1**, the main effect model of PA and health predicts that health behaviors, physiological functioning, and resources mediate (*paths a*, *b*, *c*, and *d*) the association between PA and immune and cardiovascular systems that have implications for disease (*path e*). Many studies have supported the links between initial PA and the posited mediators (e.g., **Figure 1**, *paths a* and *c*). Each of these mediators is discussed below.

Health behaviors. Likely behavioral candidates for mediators of the PA and health association include physical activity (e.g., Hoogwegt et al. 2013, Kelsey et al. 2006), sleep (e.g., Ong et al. 2017b), and medication adherence (e.g., Ironson et al. 2018). Few single studies look at more than one health behavior; in one exception, Whitehead (2016) tested the cross-sectional association between PA and a range of self-reported health behaviors (e.g., exercise, eating healthy, smoking, alcohol, sleep, flossing, seatbelt use) and found that only high-arousal PA predicted better outcomes (specifically healthy eating and exercise), and that NA did not predict these outcomes when PA was in the model.

Most of these studies are observational, but experimental evidence is beginning to accumulate, albeit with mixed results. Lab-based studies have shown that PA manipulations via film clips, music, emotional imagery, or memory evocation increased intentions to engage in physical activity (Cameron et al. 2015). PA manipulations also increased intentions to choose healthy food (Cameron et al. 2018). In clinical populations, PA inductions (e.g., via small gifts) and self-affirmation have been found to increase physical activity among coronary patients (Peterson et al. 2012) and to improve medication adherence in hypertensive populations (Ogedegbe et al. 2012). However, activity findings did not replicate in asthmatics (Mancuso et al. 2012), and medication adherence effects were not found in a population of African Americans with hypertension (Boutin-Foster et al. 2016). Combining and reanalyzing the results from three previously published self-affirmation studies (Mancuso et al. 2012, Ogedegbe et al. 2012, Peterson et al. 2012) revealed that, on average, those participants who reported at least a one-standard-deviation decline in PA from baseline to a 12 month follow-up were less likely to maintain their behavior change (Peterson et al. 2013).

Physiological functioning. Some of the most compelling and consistent evidence that PA could have a downstream health impact arises in the physiological biomarker literature. This research indicates that PA is associated with potentially health-benefiting differences in outcomes like immune function, stress hormone levels, and cardiovascular function, including in studies where PA is manipulated experimentally. For example, greater PA has been tied to healthier immune function outcomes, such as more robust vaccination responses, higher levels of circulating white blood cells, reduced inflammation, and faster healing (for a review, see Marsland et al. 2007). PA has also been associated with lower levels of the immune-altering hormone cortisol (e.g., Brummett et al. 2009, Steptoe et al. 2005); lower heart rate, blood pressure, and lipids (e.g., Blanchflower & Oswald 2008, Steptoe et al. 2005); and healthier nighttime cardiovascular activity (i.e., low nocturnal heart rate and high heart rate variability) (Bhattacharyya et al. 2008), a predictor of reduced mortality risk.

Some areas provide more mixed results, however. For example, PA has been tied to both high stress-related sympathetic activity assessed via salivary alpha amylase (Nater et al. 2007) and higher relaxation-related parasympathetic nervous system function, assessed by heart rate variability (e.g., Bhattacharyya et al. 2008). Conflicting findings can be better understood by couching the interpretation of these results in terms of the types of PA, context, and timing. Momentary high-activation PA may be tied to brief sympathetic arousal, but in the context of stress, PA is associated with lower alpha amylase (Jenkins et al. 2018a), and more stable PA is associated with lower sympathetic activity across the day (Doane & Van Lenten 2014).

While most of this work relies on one-time self-report, converging evidence from other forms of PA assessment indicates that PA expression via smiling and positive word use is similarly associated with lower heart rate, blood pressure, and cholesterol (Davidson et al. 2010, Kraft & Pressman 2012, Pressman & Cohen 2012). Another recent methodological advancement is work indicating that, beyond PA in general or any specific type of PA, the diversity of felt emotions may also matter in physiological function, for example, in immune function (Ong et al. 2017a). The research into the links between PA and physiological pathways is impressive in its breadth, depth, and replications, but one important next step will be to unpack the cyclical connections between emotion and physiology, for example, in vagal activity (Kok and Fredrickson 2010, Thayer & Lane 2000), to better understand to what extent some arrows in the described models are bidirectional, especially as new complex systems and pathways (e.g., microbiome, epigenetics, telomeres) are discovered and implicated in these findings.

Social, psychological/intellectual, and physical resources. Numerous reviews have detailed how social relationships are positively associated with healthier physiological functioning and better physical health (e.g., Kiecolt-Glaser et al. 2010), while isolation is harmful (Holt-Lunstad et al. 2015). Given the close association between social relationships and PA (Kok et al. 2013), it may be that variables such as felt support, social control, and integration operate as mediating pathways connecting PA to health.

In addition to social support variables, PA is also predictive of the accrual of other resources, including coping resources (e.g., adaptive coping, resilience) (Gloria & Steinhardt 2016) and sociodemographic factors like higher education achievement, promotions, and financial success (De Neve & Oswald 2012). Since these psychological, intellectual, and physical resources impact physical health in their own right, they offer another distinct path through which PA predicts health.

Testing the full model and conclusions. Although the majority of studies find support for the initial mediation link (i.e., **Figure 1**, *paths a* and *c*) and the association between PA and physical health (the final outcome), only a few studies have tested the full mediation prediction of this model, with physical health as the dependent variable of interest. For example, Doyle et al. (2006) assessed baseline PA, experimentally exposed participants to a rhinovirus strain, and monitored IL-6 (a marker of inflammation) and rhinovirus infection over the course of five days. They found that IL-6 mediated the association between PA and infection severity. Similarly, Hoogwegt et al. (2013) found that physical activity moderated the association between PA and mortality during a five-year follow-up period.

One reason that studies do not often test mediation may be related to the issue of timing. The predictions under the main effect model span the course of several years, even decades, due to the amount of time it would take for these types of mechanisms to have a detectable impact on physical health, especially if starting with a young and healthy population. Furthermore, the mediators in this model do not represent single occurrences that can be measured at one point [e.g., it is unlikely that hypothalamic–pituitary–adrenal (HPA) activity over a single month in one's life would fully account for the association between PA and disease].[1] Thus, researchers may consider relying on existing longitudinal data sets that assess mediators at multiple time points throughout the life span and, when designing studies, consider the issue of timing carefully when choosing assessment types, frequency, and interpretation.

Stress Buffering Models of Positive Affect

Pressman & Cohen (2005) also proposed the stress buffering model of PA, which hypothesizes that health benefits arise out of PA's ability to reduce stress and its detrimental effects on the body. For example, PA may alter stress and coping appraisals, reduce stress reactivity (i.e., the degree of change, such as blood pressure increases, in response to stress), or hasten stress recovery. These stress alterations are beneficial, as both increased reactivity and prolonged recovery have detrimental long-term health effects (Fredrikson & Matthews 1990). The stress buffering model is consistent with the revised stress and coping theory (Folkman 1997) and the broaden and build theory of positive emotions (Fredrickson 2001, Fredrickson & Levenson 1998). The revised stress and coping theory explicitly posits that PA provides a time out from the distress associated with

[1]However, if this one month was reflective of general HPA activity, then this measure may partially account for PA–disease associations.

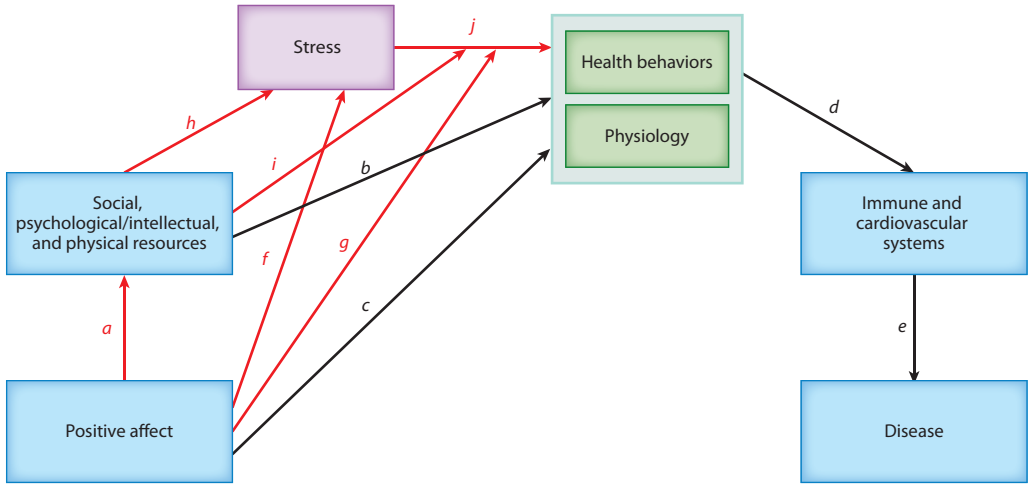

Figure 2

Adding the stress buffering model to the main effect model of positive affect. Red emphasizes paths added to the main effect model (i.e., *paths f* through *j*) or those that were in the main effect model but are also emphasized in the stress buffering model (i.e., *path a*). An absence of a line does not indicate that an association between variables does not occur, nor do arrows indicate a single direction of causality. Rather, lines drawn represent the focus of this model, and arrows go in only one direction for simplicity.

chronic stress and helps motivate and sustain ongoing efforts to cope. The broaden and build theory explains PA as evolutionarily adaptive in that it guides a person to explore and relax during safe and non-life-threatening times. These behaviors lead to the building of resources that can be called upon in other contexts, even after the positive emotion state has passed and, in particular, during times of stress. In other words, PA is proposed to have an undoing effect that hastens recovery from stress. While few objective health outcome studies have tested this effect, there is growing evidence for its importance in outcomes like mortality (e.g., Mroczek et al. 2013).

The stress buffering model makes two broad predictions: the first characterized by moderation and the second by mediation. First, PA moderates the link between stress and health behaviors and physiological functioning (in **Figure 2**, *path g* moderates *path j*; *path a* leads to *path i*, which moderates *path j*) by weakening the connection between stress and health behaviors and physiology. Second, PA may reduce the occurrence of stress in and of itself (i.e., decreasing the likelihood of experiencing stress, reducing reactivity, speeding recovery from stress), thus leading to more desirable health behaviors and physiological functioning. In this prediction, stress mediates the association between PA and health-relevant variables either directly (i.e., **Figure 2**, *paths f* and *j*) or indirectly by the resources accrued through PA (i.e., **Figure 2**, *paths a*, *h*, and *j*).

Moderation. Testing the moderation effects proposed above requires examination of the interaction term between PA and stress. Support for the idea of stress buffering comes from a significant interaction term whereby, at high levels of stress, PA is even more health protective than it is at low levels of stress. In terms of design, there are four possible study designs for testing this moderation effect: Researchers can (*a*) use random assignment for both stress and PA, (*b*) use random assignment for stress and measure naturally occurring PA, (*c*) use naturally occurring stress and randomly assign participants to receive a PA intervention, or (*d*) measure naturally occurring stress and PA. Without including a no- (or low-)stress condition, it is impossible to differentiate between the effects of PA on health at high versus low stress. Thus, studies in which there is

only a stress condition (e.g., all participants are assigned to a stress task or experience a naturally occurring stressor) are only testing part of the stress buffering model.

To our knowledge, no study has randomized the presence, absence, and level of both stress and PA. There are studies, however, that have manipulated either stress or PA. Stress is often experimentally induced through laboratory tasks (e.g., speech and pain tasks). For example, participants in an experimental wounding study were randomly assigned to give a speech or not (i.e., high versus no stress), and naturally occurring trait PA was predictive of faster wound healing only in the stress group (Robles et al. 2009). In contrast, an example of random assignment to PA with measurement of naturally occurring stress comes from Charlson et al. (2013), who found that individuals in a PA intervention who experienced naturally occurring stress over the study period had greater health behavior change as compared to participants in the control group. Finally, considering studies testing both naturally occurring stress and PA, Blevins and colleagues (2017) reported that PA moderates the link between stress and C-reactive protein levels (a marker of inflammation) such that, at higher stress levels, higher PA is predictive of lower C-reactive protein levels. Surprisingly, high PA paired with high stress resulted in more favorable C-reactive protein levels as compared to low-stress conditions regardless of PA, suggesting that, at least in some cases, high stress is associated with more favorable outcomes.

Mediation. PA likely not only moderates the effect of stress on health behaviors and physiology, but also has a direct effect whereby it decreases stress (or makes it less likely that a person experiences stress), which then leads to more favorable outcomes. This process by which PA reduces stress is a test of mediation (**Figure 2**, *paths f* and *j*; **Figure 2**, *paths a*, *h*, and *j*). Indeed, numerous studies find evidence that PA directly reduces self-reported stress (e.g., Bono et al. 2013). Investigators aiming to test this question of mediation should assess PA, stress, and health behaviors and physiological function to determine whether stress mediates the link from PA to health behaviors and physiological functioning. Unfortunately, few studies have aimed to explicitly test this mediation; however, Charlson and colleagues (2013) found that increases in PA were associated with decreases in stress, which were eventually associated with increases in beneficial health behavior change in patients with chronic cardiopulmonary disease.

Conclusions. There are considerations that should be taken into account when testing the stress buffering model (whether it be via moderation or mediation) or applying it in practical contexts. First, it is important to determine whether positive emotions happen naturally during stress, or whether interventions need to be designed to increase PA during stressful experiences. Evidence for the former possibility comes from Fredrickson & Levenson (1998), who found that almost 70% of their participants spontaneously smiled during negative stimuli (which aided cardiovascular recovery). However, if positive emotions need to be induced during times of stress, careful consideration should be made with regard to context and methods of induction. For example, immediately following cancer diagnosis, it may be inappropriate to engage in certain PA interventions. In contrast, during a brief painful procedure (e.g., flu shot), these same interventions may be quite helpful. Second, it is important to identify a priori whether variables are mediators, moderators, or outcome variables. When testing the stress buffering model, health behaviors and physiological functioning may be outcome variables of interest, but they may also be mediators that lead to changes in immune and cardiovascular system functioning.

Future Directions in Models

The majority of the PA and health literature and theories focus on broad PA assessments. However, there is value in examining the differential effects of PA subtypes and how these effects factor into

the specifics of the disease biology or stress context. As shown above, high-arousal PA may be beneficial in some health outcomes (e.g., mortality) but harmful in other physiological processes in which arousal can be damaging (e.g., pain). This may also be true for stress. For example, during times of average to low stress, low-arousal PA is most beneficial for helping students get good sleep, but during very high exam stress that requires active coping, trait high-arousal PA is most helpful (Pressman et al. 2017). Therefore, PA might work best when the arousal level of PA matches the needs of the individual, the context, and, when relevant, the specific stressor. For example, during times of stress when an active coping style is necessary, high-arousal PA may provide an individual with the necessary energy to engage in active coping. Although most studies do not take arousal level into account, there is clearly evidence that health findings differ based on positive arousal, as well as evidence that high-arousal PA is beneficial during active stress (Brooks 2013).

DOES INTERVENING ON POSITIVE AFFECT IMPROVE HEALTH?

Spurred by the growing evidence that PA uniquely predicts health outcomes, there is great interest in designing positive psychology interventions that will benefit health. The guiding hypothesis for this work is that the interventions will increase PA, which will then, via the paths described above (e.g., health behavior change, stress reduction), improve physical health. This literature is new, with few studies to date focusing on physical health outcomes. Thus, in this section, we summarize promising PA-relevant intervention effects in samples with chronic illness. Also highlighted are real-world, applied interventions meant to have enduring effects on PA (and health), as opposed to studies of transient emotion induction in the lab (known to alter physiology in the moment but unlikely to have long-term health effects).

Most published interventions in people living with chronic illness utilize a multicomponent approach (i.e., they teach a range of positive skills rather than focusing on a single activity type). This buffet-style intervention makes sense, given that there are not enough data at this point to pick a targeted manipulation type, and there is evidence that individuals like having more than one choice of activity (Schueller & Parks 2012). Intervention activities arise primarily out of research in positive psychology, where ways to increase PA and related positive factors have been found. Such interventions focus on topics like engaging in acts of kindness, practicing gratitude, trying to extend positive events by savoring them, practicing personal strengths, imagining best possible selves, thinking optimistically, and engaging in different forms of mindfulness. Together, these activities have been repeatedly shown to improve psychological well-being (including PA) and decrease depressive symptoms, with small effect sizes in the general public as well as in individuals with mental health concerns (rs in the 0.2–0.35 range) (e.g., Bolier et al. 2013). Thus, there is good reason to think that, in populations with chronic illness, benefits could also occur, helping these individuals cope with the adverse negative experiences of a major life threat and, perhaps, improving their psychological and physical well-being.

Studies in the growing field of PA interventions in ill populations, while impressive in breadth, have a range of quality levels. For example, few studies have sufficient sample size, strong control conditions, diverse samples, and the high retention rate required for definitive conclusions. However, even with these interpretative limits in mind, there is promising work showing that PA can be increased in a wide range of ill samples, such as those with heart disease (Huffman et al. 2016), diabetes (although only for those recruited online; Cohn et al. 2014), early stage cancer (for a review, see Casellas-Grau et al. 2014), and newly diagnosed HIV (Moskowitz et al. 2017), with some studies showing that PA benefits remained over a year after the PA intervention was complete. Studies in patients with advanced cancer show fewer significant effects of PA, although

the sample sizes are generally small, so researchers should not overinterpret these findings (e.g., Cheung et al. 2017).

While the PA intervention literature is promising, little work has found objective health-altering effects, and PA has not yet been demonstrated to be a mediator between intervention and health. Still, early evidence indicates small to moderate effect sizes of a PA skills training intervention on viral load suppression and reduced need for opioid analgesics in people living with HIV (Addington et al. 2018, Moskowitz et al. 2017), and real-world PA interventions have been tied to elevated vagal tone, a marker of physiological relaxation and heart health (Kok & Fredrickson 2010). Studies of individuals living with hypertension have not found benefits from self-affirmation (Boutin-Foster et al. 2016, Ogedegbe et al. 2012); however, in a healthy population, a brief prosocial spending intervention led to reduced blood pressure (Whillans et al. 2016). It is clearly too early to determine whether and when PA interventions will have benefits for those living with chronic illness. The field has barely begun to answer questions like which delivery format is most effective (e.g., online, in person, by phone), how many sessions are needed, and which components (e.g., gratitude, acts of kindness, savoring) have the greatest impact, all critical questions that need exploration.

As researchers move forward on these questions, it will be important to start with a theoretical framework that guides the selection of intervention components and PA measurement targets, as well as careful consideration of what mechanisms might be most relevant. For example, taking cardiovascular disease as the outcome, physical activity is one likely mechanism connecting PA to better heart function. Thus, it might behoove researchers to focus on higher-activation types of PA that predict physical activity (e.g., Hoogwegt et al. 2013) and on interventions that impact that type of PA. Complicating this approach is the fact that most positive interventions increase a range of positive constructs (e.g., PA but also life satisfaction, optimism, hope, happiness) (Mohammadi et al. 2018), as well as decreasing negative outcomes (e.g., intrusive and avoidant thoughts, use of mood altering drugs) (e.g., Moskowitz et al. 2017). This makes a targeted approach more difficult (since it is hard to pinpoint the active ingredient), but it also makes interventions potentially more efficacious if the psychobehavioral outcomes work together to promote health in a similar direction. In addition, a guiding framework emphasizing basic science during intervention development will increase the likelihood that health-related interventions are maximally effective and successfully implemented in applied clinical settings. Furthermore, a systematic approach that includes factors like disease stage and the specific psychological needs at that stage will result in stronger evidence to optimally tailor interventions to the disease course. This could contribute to more options for conducting interventions that go beyond a focus on individual behaviors, potentially to larger systems-level interventions that can have a much broader impact on public health.

FUTURE DIRECTIONS FOR DESIGN, METHODOLOGY, AND STATISTICAL PRACTICES

As researchers move forward in the study of PA and health, there are many additional issues to consider beyond what is discussed above. Central issues include exploring covariates, mediators, and moderators; considering other statistical methods; dealing with other positive constructs; and utilizing new technology in the field.

Covariates, Mediators, and Moderators

Careful consideration should be given to which variables are treated as covariates, which are treated as mediators, and which are treated as moderators. For example, sociodemographic variables might

be possible covariates or, alternatively, play important roles as moderators. Pressman & Cross (2018) outlined how cultural differences in the emotions that individuals idealize (Tsai 2007) may alter whether certain types of PA are beneficial for health. If the desired state is low arousal, but an individual feels high in arousal, will it be helpful or harmful? This question remains unanswered, but researchers are starting to investigate ideal affect in the context of medical outcomes (Sims et al. 2014). Related to ideal affect, geographic location (e.g., country) may also play a role in the PA–health relationship, as evidenced by a study indicating that the PA–health association is more robust in poorer countries, even after accounting for NA and basic needs (Pressman et al. 2013). This may be due to the ability of advanced medical technology and resources to ameliorate some of the negative effects of affect variables in more affluent countries. Finally, it is critical that age be more regularly treated as a moderator. As evidenced by the mortality data, PA matters more for health in later stages of life, when chronic disease processes are more relevant and PA has the ability to alter mechanisms that lead to changes in these processes. Complicating this line of research are the changes in PA as individuals age, such as an increase in positivity but also a preference for lower arousal (Charles & Carstensen 2010). What does this mean for the high-arousal PA findings on mortality? Is high-arousal PA beneficial in these older samples because it is less common and only found in the healthiest aged adults? More research on this topic, especially research that carefully disentangles the interconnections among age, health, and affect, is needed.

Given that any effect of PA may be partially or fully explained by an absence of NA, it has been long advocated that NA or related negative constructs should be adjusted for in PA–health models (e.g., Chida & Steptoe 2008, Pressman & Cohen 2005). Most, but not all, of the studies reviewed in this article include some negative measure as a covariate. Since many PA measures are highly correlated with NA (Diener & Emmons 1984), including both PA and NA measures in the same model can be difficult, leading many researchers to control for depression or anxiety measures instead (e.g., Lambiase et al. 2015). This results in analyses controlling for symptoms that travel with depression or anxiety, such as difficulties with concentration, self-injury, eating, and sleep (Kroenke et al. 2001, Radloff 1977). The approach of using clinical tools rather than NA results in interpretative differences in the meaning of the adjustment. Thus, researchers should be specific about the meaning of the negative construct that is covaried, honest regarding its limitations, and open to utilizing other methods. For example, research could report the effects of both NA and PA or utilize affect balance or ratio approaches to see whether NA and PA factored together have better explanatory power. While ratio research has been controversial (Brown et al. 2013, Fredrickson & Losada 2005), and affect balance results have been mixed, these statistical approaches can provide information on whether it is beneficial to have more PA relative to NA. They cannot, however, indicate if one variable is more important than the other or say anything about active subcomponents. To date, there are few data on the health value of ratios (for one example in type 2 diabetics, see Steinhardt et al. 2015) and affect balance (e.g., Hassett et al. 2008), but such work can help inform whether interventions should target increasing PA, decreasing NA, or both.

Statistical and Design Considerations

Though rarely discussed, it is important to consider that the association between PA and health may not be linear; for example, studies have revealed that a medium amount of high-arousal PA is best for cardiovascular outcomes (Armon et al. 2014). Relatedly, new work in the area of PA and health is moving beyond modeling average levels of PA by exploring PA variability, PA reactivity, and patterning of PA. For example, higher PA variability is associated with poorer self-reported physical health and a greater likelihood of illness diagnosis (Chan et al. 2016). Similarly, larger

PA reactivity to stress (i.e., larger drops in PA resulting from daily stressors) on a day-to-day basis has been associated with increased mortality in a 10-year follow-up, even when assessed over just a few days (Mroczek et al. 2013). In contrast, individuals who experience increasing PA over the course of the day have the lowest risk of current and future coronary artery calcification (Kroenke et al. 2012). Mroczek and colleagues (2006) argued that one possible reason for some health detriments of variability and reactivity is that this rapid change in emotion may overengage certain physiological stress pathways, in much the same way that stress reactivity has been argued to have downstream health effects. This change might also impact negative health behaviors, but generally, the mechanisms underlying why frequent ups and downs in affect might be harmful are unstudied. It is also beneficial to consider interactions between variability and mean levels of PA, which have implications for health (e.g., Jenkins et al. 2018b, Ong & Ram 2017). Furthermore, novel approaches may be needed to deal with the possibility that certain types of patterning of PA (e.g., patterns of change that repeat) may matter in health outcomes (Jenkins 2017). Thus, it is clear that advanced statistical approaches have begun to increase our understanding of the dynamics of PA and their relationship to health, but more work in this area is needed to know when and how these associations occur.

As alluded to above, issues of reverse causality often arise in this line of research, especially when there is conceptual or item overlap between the PA and health measures. Resources, health behaviors, and physiological functioning may all be variables that lead to changes in PA. Therefore, in relation to study design, it is important to accumulate prospective or experimental data in which PA is assessed or induced before changes in these variables and in which health is carefully controlled in multiple ways (e.g., self-report, objective) at baseline so that confidence that it is truly PA that is predicting health can be bolstered.

To date, research on the relationship between emotion and health has mostly been left out of discussion of the replication crisis and other growing methodological concerns (e.g., Maxwell et al. 2015), possibly due to the high cost of work in this field (e.g., large longitudinal samples requiring decades of follow-up, expensive biomarkers). For this reason, PA and health researchers must be especially vigilant to ensure that studies are high quality. Bayesian frameworks, in which traditional hypothesis testing is set aside in favor of estimating coefficient distributions, should be considered, as should studies that preregister hypotheses and covariate selection to reduce the likelihood of atheoretical fishing expeditions. While it is easy for the media to sensationalize a single finding on happiness predicting health, researchers must be persistent in conceptually or directly replicating findings to test the robustness and generalizability of the connections found.

Dealing with Other Positive Constructs

While correlated with these factors, PA is distinct from other measures of well-being like life purpose, life satisfaction, and optimism, which are sometimes described as more conscious and cognitive judgements and which can be focused on different time assessments (e.g., expectations for the future). While it is clear that many of these measures also have robust associations with health, the mechanisms by which these measures influence health may be different than those that apply to PA. To add complication, in some cases, PA is a pathway by which these other positive variables influence important outcomes such as immunity and airway function (e.g., Crittenden et al. 2014, Segerstrom & Sephton 2010), yet in other cases, PA operates as a moderator (Nater et al. 2010). Therefore, what is also needed is a broader theoretical model examining how the widely studied range of positive constructs in health research (Cross et al. 2018) fit and work together to foster health in different contexts. Do they have unique paths? Are certain components helpful at certain time points of disease or for certain types of disease? Do constructs operate via similar mechanisms?

For example, do trait and eudaimonic measures influence health via their influence on day-to-day and state PA? Careful consideration of these questions will be necessary given the high degree of statistical overlap among some of these factors; thus, as with factors of NA, researchers must carefully consider how to deal with these factors from a theory-based perspective.

New Technology

As in many areas of psychology and medicine, exciting technological developments will enable breakthroughs in this field. Wearable biosensing devices will advance our knowledge of how varying emotion in the real world translates into changes in behavior and physiology on a moment-to-moment basis. Newer, better, and easier mobile data collection platforms will encourage real-time and real-world approaches that address critiques and biases of one-time in-lab approaches and enable better assessments of affect variability. Finally, big data sets available through the push for open science, growing electronic hospital records, social media, and companies assessing large amounts of genetic and microbiome data will certainly lead to new discoveries, as will machine learning approaches to analyzing and synthesizing these massive amounts of data.

CONCLUSIONS

Positive psychology comes under regular attack from critics, perhaps due to cynicism regarding the idea that something that seems so intangible and unscientific could have real health effects, confusing societal attitudes about happiness with empirical findings, or the endless list of happiness self-help books published by nonresearchers. With this in mind, the PA and health literature has faced multiple attacks on the value of positivity for health (e.g., Nickerson et al. 2018). Nevertheless, these claims have been well defended (e.g., Fredrickson & Kok 2018), and earlier findings have been replicated and extended (e.g., Fredrickson et al. 2015, Isgett et al. 2017). One possible reason for this focused criticism is the belief in the "tyranny of the positive attitude" (Held 2002, p. 965), but by no means does health research, or positive psychology for that matter, ignore or dismiss the role of negative emotions. To find evidence that positive factors have a unique role in health, researchers often work all the harder to demonstrate that PA effects are unique and not simply the opposite of NA. Meanwhile, researchers in depression, hostility, and anger are not expected to do the same with regard to PA. Moreover, it has also been previously suggested by PA and health researchers that too much positivity might be harmful under some circumstances. For example, high-activity positive emotions might be harmful in conditions exacerbated by arousal (e.g., asthma, irritable bowel) or in end-stage diseases where positivity may lead to earlier death. For the latter, it may be that high PA in the face of threat could decrease the likelihood of care-seeking behavior or reduce vigilance about symptoms (for discussion, see Pressman & Cohen 2005). Manic PA can also be harmful in numerous circumstances (for discussion, see Diener & Chan 2011). Thus, there has already been serious consideration of a balanced approach to how and when PA is helpful versus harmful and how this plays out in concert with NA (such as work on ratios and affect balance).

Together, this research is compelling and promising. While it is early in terms of the potential of intervention research to build health, the cross-sectional and longitudinal data showing connections between PA and disease- or mortality-relevant outcomes are difficult to ignore. There are still important gaps in the literature. There is a need for thoughtfully picked PA measurement tools partnered with health outcomes and plausible mediators in a single study. There are also missing types of studies, such as designs manipulating both stress and PA. That said, in the larger body of evidence showing a broad array of probable physiological, social, and behavioral

connectors, it seems only a matter of time before all the pieces come together. Thus, there is reason to be optimistic about this literature and its future. That said, given the widespread public and media interest in this topic, researchers must monitor themselves carefully. Given the myriad ways that PA can be operationalized and the complexity of health pathways and outcomes, no single study can provide a definitive answer to the question of whether PA reliably predicts a healthier or longer life. Well-designed and well-controlled studies are expensive and time consuming, as evidenced by the important methodological issues discussed above; thus, each study should be considered as a valuable and necessary way to complete the larger puzzle. Researchers must also begin to investigate how this work can be used to improve the health of the populace to draw public policy makers' and funders' attention. Only with this approach can researchers hope to convince doctors, public health experts, and policy makers that PA and health work is uniquely valuable and that it has the potential to help people live longer, healthier, and higher-quality lives.

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