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Life satisfaction and inflammation in couples: an actor–partner analysis

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Abstract Life satisfaction has been linked to lower cardiovascular disease mortality. However, much less is known about the biological mechanisms linking life satisfaction to physical health. In addition, the dyadic context of life satisfaction has not been considered despite increasing evidence that partners influence each other in health-relevant ways. These questions were addressed with 94 married couples who completed measures of life satisfaction and had their blood drawn for determination of interleukin-6 (IL-6) and C-reactive protein (CRP). Actor–partner models showed that higher actor levels of life satisfaction predicted lower levels of IL-6 and CRP (p's $< .05$), whereas partner levels of life satisfaction did not predict any measure of inflammation. The actor results were not mediated by marital satisfaction or health behaviors. Finally, no actor × partner interactions were significant and these links were not moderated by marital satisfaction. These data highlight inflammation as a potentially important biological mechanism linking actor reports of life satisfaction to lower cardiovascular mortality.

Keywords Life satisfaction · Dyadic · Actor–partner models · Inflammation

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Introduction

Satisfaction with life represents the cognitive component of subjective well-being and reflects a general cognitive evaluation regarding one's life across different domains (e.g., social, health, work; Diener et al., 2013). It is distinct from other measures of subjective well-being such as positive and negative affect which reflect the affective aspects of subjective well-being (Pavot & Diener, 2008). Although most research has focused on life satisfaction as an outcome (Diener et al., 2013), research suggests that it is also a predictor of diverse outcomes including better job performance (Erdogan et al., 2012) and relationship stability (Luhmann et al., 2012). Importantly, life satisfaction also predicts better physical health, including lower cardiovascular disease mortality which is the number one cause of death in most industrialized countries (Boehm & Kubzansky, 2012). Life satisfaction is thought to facilitate positive outcomes by promoting psychological and behavioral adaptations to life challenges such as seeking support and adaptive coping during stress (Kohler Giancola et al., 2009; Trepte et al., 2014).

Despite this evidence, there are several important issues that need to be addressed. A first issue is that only a few studies have examined if satisfaction with life is associated with biological outcomes that might explain epidemiological links to long-term health. Life satisfaction is most consistently linked to cardiovascular disease so inflammation is likely to be an important biological pathway (Kiecolt-Glaser et al., 2010). Immune-mediated inflammation influences every stage of cardiovascular disease from the initiation of early endothelial injury to later arterial obstruction or plaque rupture (Libby et al., 2016; Ross, 1999). Two important markers of inflammation include interleukin-6 (IL-6) and C-reactive protein (CRP) which

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predict future risk for cardiovascular disease and related mortality (Bisoendial et al., 2010; Hunter & Jones, 2015; O Hartaigh et al., 2013). To date, only three studies appear to have tested the link between life satisfaction and inflammation: Two have found life satisfaction to predict lower CRP and IL-6 levels (Hamer & Chida, 2011; Nowakowski, 2014) while the other study did not (Rissanen et al., 2013). Thus, more research is needed modeling these inflammatory biological pathways.

A second issue is that none of the studies examining life satisfaction and inflammation utilized a dyadic approach which is important for both statistical and conceptual reasons. At a statistical level, it is possible that dyadic approaches provide a more sensitive test of links between life satisfaction and inflammation as they directly model important actor and partner sources of variance. In this context, actor influences represent the extent to which one's own life satisfaction predicts one's own inflammation, whereas partner influences represent the extent to which a partner's life satisfaction influences one's own inflammation (Reed et al., 2013). Separating out these unique sources of variance should clarify the relative contribution of each dyad member and whether one member is more highly related to inflammation than the other.

At the conceptual level, dyadic approaches are of importance because they explicitly model how the social context influences the link between psychological factors and health (Pietromonaco et al., 2013). Most of the work in this area has focused on how relationships influence life satisfaction (Adams et al., 1996; Burton-Jeangros & Zimmermann-Sloutskis, 2016; Cheng et al., 2011; Heckman, 2003; Sherman et al., 2004). This literature demonstrates that better quality relationships are associated with higher levels of life satisfaction (Burton-Jeangros & Zimmermann-Sloutskis, 2016; Dyrdal et al., 2011). In one study, for women in low quality marriages, life satisfaction increased upon divorce (Bourassa et al., 2015). However, a limitation of this literature is that many of these studies are cross-sectional and thus cannot address whether there are bidirectional associations between life satisfaction and relationship outcomes. Through such mutual influences life satisfaction may also influence relationship outcomes over time (Gustavson et al., 2016; Luhmann et al., 2013; Norman et al., 2012). In fact, Gustavson et al. (2016) in a study of romantic couples found evidence that life satisfaction prospectively predicted better relationship quality over a 3 year period. Similarly, it has been found that life satisfaction is a prospective predictor of lower divorce rates (Luhmann et al., 2013).

Marriage is an especially important social context in which to study health-relevant dyadic processes. It is one of the most important relationships in adulthood and partners mutually influence each other for better or worse (Robles et al., 2014; Smith et al., 2011). Consistent with this possibility, data from the Seattle Longitudinal Study found that changes in life satisfaction over a 35 year period were linked within couples (Hoppmann et al., 2011; also see King et al., 2016 for a shorter follow-up). Such data illustrate that partners' levels of life satisfaction can influence each other over time. However, no studies to date appear to have examined if actor–partner life satisfaction scores are related to health-relevant biological processes. Given links between life satisfaction and health-relevant social processes, directly modeling dyadic processes can provide unique insight into the social context of health (Pietromonaco et al., 2013).

The present study thus examined actor–partner models linking life satisfaction to inflammatory outcomes (i.e., IL-6 and CRP) in married couples. Based on the larger epidemiological literature (Boehm & Kubzansky, 2012), it was predicted that one's own perceptions of life satisfaction (actor influences) would be related to lower levels of both IL-6 and CRP. Different predictions regarding partner influences of life satisfaction on inflammation were possible. On the one hand, dyadic models suggest that partners mutually influence each other in health-relevant ways so one might expect partner levels of life satisfaction to predict lower inflammation (Pietromonaco et al., 2013). On the other hand, life satisfaction reflects a broad assessment of satisfaction across different domains of life (e.g., marriage, work; Diener et al., 2013). Thus it is possible that a partner's level of life satisfaction might not be related to inflammation because it primarily reflects partner influences within the marital domain. Ancillary analyses thus considered if marital satisfaction mediated any significant links between life satisfaction and inflammation. It is also possible that actor–partner life satisfaction influences inflammation via health behaviors (Diener & Chan, 2011). For instance, actors and partners who have greater life satisfaction might be more likely to exercise together. Thus, secondary mediational analyses also considered if any associations were due to health behaviors.

Method

Participants

Ninety-four relatively healthy married middle-age to older adult couples were included in this study ($M_{age} = 56.2$, $SD = 7.30$, range 42–78 years). Couples were married on average for 27 years ($sd = 11.5$). The present study was part of a larger study that investigated social interactions and cardiovascular health in middle-aged and older adults because they have an elevated cardiovascular disease risk

(Uchino et al., 2013). Most were White (94.6%) and had an income over $40,000 per year (87.6%). Many older adults are on some form of medication so only individuals who (a) were on strong immunosuppressive treatment (e.g., corticosteroid therapy) and/or (b) had cancer or HIV were excluded due to concerns about potential effects of treatment on inflammation.

Procedure

Eligible participants were screened via phone interviews and scheduled for a laboratory appointment at the Social Neuroscience II Laboratory during a 3-h late morning block (9 am to 12 pm) to control for diurnal influences on inflammation. Following informed consent, participants were first rechecked against the exclusion criteria upon their arrival for their session. Participants then completed demographic and health questionnaires and life satisfaction/marital assessments (see below). Approximately 20 cc of blood was also drawn and treated with EDTA to prevent clotting. Plasma was separated via centrifuge and levels of IL-6 and CRP were determined at a research laboratory at the University of Amsterdam (see below). Couples were then debriefed and received $60.00 each for their participation.

Measures

Health assessment

A standardized health questionnaire provided information on the following potential health-related variables: medications/medical condition (0 = no, 1 = yes), frequency of exercise, use of tobacco products (0 = no, 1 = yes), weekly alcohol consumption, and body mass index. The health behavior questionnaire has been used in a large longitudinal study on the chronic stress of caregiving for a relative with Alzheimer's Disease and its effects on physiological function (see Kiecolt-Glaser et al., 1991).

Satisfaction with life scale (SWLS)

The SWLS is a 5 item scale that measures general life satisfaction (Diener et al., 1985). The SWLS is characterized by high internal consistency (e.g., alpha of 89) and good test–retest reliability (e.g., 4 year test–retest reliability of .54, Pavot & Diener, 1993). The internal consistency of the scale in this study was likewise high (alpha = .84).

Marital adjustment test (MAT)

The MAT contains 15 items and is a widely used measure of overall marital quality (Beach et al., 2005; Locke & Wallace, 1959). Its psychometric properties are well documented and reliably distinguishes distressed from non-distressed couples (Beach et al., 2005). The internal consistency of the scale in the present study was high (alpha = .80).

Inflammation assessments

High sensitivity CRP (hsCRP) was measured by immunonephelometry using a Behring Nephelometer II. The limit of detection for C-reactive protein is 0.015 mg/L (High Sensitivity CRP, Dade Behring). All samples were assayed in the same run, yielding a within-assay CV% of <4.5% for hsCRP. IL-6 was determined using a commercially available high-sensitivity ELISA (hsIL-6 Quantikine, R&D systems), which has a lower detection limit of 0.15 pg/ml and yielded an intra-assay CV% of <6%. Consistent with prior work, CRP and IL-6 weres natural log transformed to normalize the distribution prior to analyses (Mezuk et al., 2010). The non-normality of the data was confirmed by significant Shapiro–Wilk tests for CRP ($W = .67$, $p < .001$) and IL-6 ($W = .83$, $p < .001$) which is one of the most powerful tests of normality based on Monte Carlo simulations (Razali & Wah, 2011).

Statistical model

Proc mixed (SAS institute) was utilized in order to test these actor–partner models (Campbell & Kashy, 2002). All factors were treated as fixed (Nezlek, 2008) and proc mixed treats the unexplained variation within individuals as a random factor. All variables were grand mean centered prior to analyses (Wu & Wooldridge, 2005). The covariance structure for the repeated measures factors of dyad (i.e., 1 = husband, 2 = wife) was modeled using the compound symmetry structure (Campbell & Kashy, 2002). The outputs of these models were unstandardized parameter estimates (b) using the Satterthwaite approximation to determine the appropriate degrees of freedom (Campbell & Kashy, 2002). Mediational analyses were conducted using the Monte Carlo method (Preacher & Selig, 2012). The MCMED macro (Hayes, 2013) was used to construct 95% confidence intervals for each indirect effect using 20,000 resamples.

Results

Descriptive analyses

Descriptive data and correlations among the main study variables are included in Tables 1 and 2. The mean

Table 1 Sample characteristics

Variable	Sample
Mean (SD)	
Age	56.2 (7.25)
Body mass	26.4 (4.76)
Life satisfaction	27.5 (4.85)
Marital satisfaction	117.4 (24.96)
Raw IL-6	1.57 (1.05)
Raw CRP	0.19 (0.25)
Exercise frequency (h/week)	3.9 (0.91)
Alcohol consumption (drinks/week)	3.5 (7.87)
Frequency	
Ethnicity (% White)	94.4%
Income over $40,000	87.7%
Statin use (% yes)	7.8%
Anti-inflammatory use (% yes)	26.8%
Hormone replacement use (% yes)	5.6%
Smoker (% yes)	2.2%

untransformed CRP and IL-6 level in the sample were .19 ($sd = .25$) and 1.57 pg/ml ($sd = 1.05$), respectively. Consistent with prior work, IL-6 and CRP levels were positively correlated ($r = .52, p < .001$). The average level of life satisfaction in the sample was 27.5 ($sd = 4.85$). Actor–partner life satisfaction scores were also positively correlated as expected ($r = .34$, $p < .001$). However, the correlation suggests only a moderate association within dyads for life satisfaction.

Main analyses

Analyses aimed at testing the major aims of the study were conducted next. These analyses statistically controlled for extraneous factors related to inflammation including age, gender, and body mass (O'Connor et al., 2009). Specific medications linked to inflammation (i.e., statins, anti-inflammatory, hormone replacement therapy, Georgiadou & Sbarouni, 2009; Libby et al., 2002; O'Connor et al., 2009) were also statistically controlled. As shown in Table 3, after considering basic demographics and medication use, actor levels of life satisfaction were a consistent predictor of lower inflammation. One's own satisfaction with life predicted both lower IL-6 ($b = -.02$, $SE = .008$, $p = .03$) and CRP ($b = -.05$, $SE = .02$, $p = .01$) levels (see Fig. 1). In comparison, partner levels of life satisfaction did not predict either IL-6 ($p = .68$) or CRP ($p = .93$).

Given the pattern of results, the mediating contribution of marital satisfaction was examined. Life satisfaction has the potential to influence inflammation through many routes, one of which may be marital functioning. All analyses included eight covariates: Partner satisfaction with life, body mass index, age, household income, gender, and medication use (3 variables). Actor satisfaction with life was a strong predictor of marital satisfaction, $b = 1.66$, $SE = .36$, $p < .001$. However, marital satisfaction did not in turn predict IL-6, $b = -.00007$, $SE = .001$, $p = .97$, or CRP, $b = .006$, $SE = .004$, $p = .11$. Monte Carlo simulations revealed that marital satisfaction did not mediate the associations between actor satisfaction with life and either of the indicators of inflammation. The direct effect of actor satisfaction with life on IL-6 remained significant with marital satisfaction included in the model, $b = -.02$, $SE = .009$, $p = .04$, and no indirect effects emerged for marital satisfaction, 95% CI [−.006, .006]. Similarly, the direct effect of actor satisfaction with life on CRP remained significant with marital satisfaction included in the model, $b = -.05$, $SE = .02$, $p = .007$, and no indirect effects emerged for marital satisfaction, 95% CI [−.002, .02]. These ancillary analyses which more directly consider the marital context are consistent with the weaker than anticipated partner life satisfaction influences on inflammation.

Given that health behaviors influence inflammation (O'Connor et al., 2009), multilevel mediational analyses were also examined considering the contribution of exercise frequency, smoking status, and weekly alcohol consumption to the actor life satisfaction and inflammation link. After consideration of the covariates, actor satisfaction with life did not predict exercise, $b = .02$, $SE = .01$, $p = .21$, or smoking, $b = -.003$, $SE = .003$, $p = .26$, although actor satisfaction with life did predict greater alcohol use, $b = .28$, $SE = .11$, $p = .02$. None of the three potential mediators—exercise, $b = -.04$, $SE = .04$, $p = .37$, smoking, $b = .01$, $SE = .24$, $p = .95$, or alcohol use, $b = .004$, $SE = .005$, $p = .38$—predicted IL-6. Additionally, neither exercise, $b = -.10$, $SE = .10$, $p = .33$, nor alcohol use, $b = -.0004$, $SE = .01$, $p = .97$, predicted CRP, although there was a significant effect of smoking on CRP, $b = 1.35$, $SE = .57$, $p = .02$. Finally, Monte Carlo simulations revealed that none of the three health-related behaviors mediated the associations between actor satisfaction with life and either of the indicators of inflammation. The direct effect of actor satisfaction with life on IL-6 remained significant with the three potential mediators included in the model, $b = -.02$, $SE = .008$, $p = .03$, and no indirect effects emerged for exercise, 95% CI [−.004, .001], smoking, 95% CI [−.002, .002], or alcohol use, 95% CI [−.002, .005]. Similarly, the direct effect of actor satisfaction with life on CRP remained significant with the three potential mediators included in the model, $b = -.04$, $SE = .02$, $p = .05$, and no indirect effects emerged for exercise, 95% CI [−.008, .003], smoking, 95% CI [−.004, .003], or alcohol use, 95% CI [−.007, .007].

Table 2 Zero order correlations among main study variables for women (top panel) and men (bottom panel)

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. SWL	1.00	−.02	.00	.07	−.14	.00	.15	.35**	.01	−.18
2. BMI	−.25	1.00	−.05	.03	.20	−.04	.18	−.10	.48**	.51**
3. Age	−.05	−.04	1.00	.19	−.17	.09	.11	−.06	.06	−.11
4. Statin	.06	−.01	.24*	1.00	.03	.05	.03	.07	.08	.01
5. Inflam.	−.06	.04	−.05	.08	1.00	.02	−.15	−.18	−.09	.21
6. HRT	–	–	–	–	–	1.00	.06	.00	−.14	.13
7. Income	−.07	−.02	−.01	.08	.08	–	1.00	.03	.06	−.07
8. MAT	.39**	−.21*	−.05	.06	−.10	–	−.02	1.00	.01	.10
9. IL-6	−.32**	.48**	.10	.09	−.04	–	.07	−.18	1.00	.47**
10. CRP	−.23*	.33**	−.04	.05	.02	–	.06	−.13	.59**	1.00

SWL satisfaction with life, *BMI* body mass index, *Inflam.* anti-inflammatory, *HRT* hormone replacement therapy, *MAT* marital adjustment test
* $p \leq .05$; ** $p \leq .01$

Table 3 Main actor–partner life satisfaction results on inflammation

Variable	IL-6			CRP		
	b	*SE*	*p*	*b*	*SE*	*p*
Body mass	.06	.008	.001	.10	.02	.001
Age	.005	.006	.42	−.01	.01	.24
Gender (male–female)	.36	.08	.001	.33	.18	.07
Statin	.14	.15	.34	.22	.33	.51
Anti-inflammatory	−.19	.09	.03	.10	.19	.60
Hormone replacement	−.30	.16	.06	.58	.37	.12
Income	.02	.04	.64	−.03	.08	.69
Actor life satisfaction	−.02	.008	.03	−.05	.02	.01
Partner life satisfaction	−.003	.008	.68	.002	.02	.93

Finally, two sets of post hoc moderator analyses were run to potentially examine if partner influences of life satisfaction were more important under certain conditions. First, moderator analyses were conducted to examine if actor × partner life satisfaction interactions were present in predicting inflammation. These analyses tested the possibility that it is the combination of actor and partner life satisfaction that might be important. Contrary to this possibility, there were no significant actor × partner interactions on IL-6 ($p = .19$) or CRP ($p = .37$). The second set of analyses tested if any of these partner results were moderated by marital satisfaction. That is, might partner life satisfaction have more of an impact if marital quality was high? None of these analyses revealed any significant partner life satisfaction × marital quality interactions for IL-6 ($p = .12$) or CRP levels ($p = .80$).

Discussion

The main aim of this study was to consider dyadic links between life satisfaction and inflammation by utilizing actor–partner models. As predicted, one's own life satisfaction was a significant and consistent predictor of lower inflammation as indexed by IL-6 and CRP. However, partner levels of life satisfaction were not related to any of the inflammatory markers, and post hoc moderator analyses also did not reveal conditional effects. Finally, the link between actor levels of life satisfaction and inflammation was not mediated by marital satisfaction or health behaviors. These data add to the broader epidemiological literature by highlighting inflammation as one biological mechanism that may explain how reports of one's own life satisfaction predicts lower mortality rates (Gana et al., 2016; Kimm et al., 2012).

As hypothesized, actor influences of life satisfaction were found on both IL-6 and CRP. These observations confirm and extend the few studies testing inflammation as a potentially important biological pathway underlying the

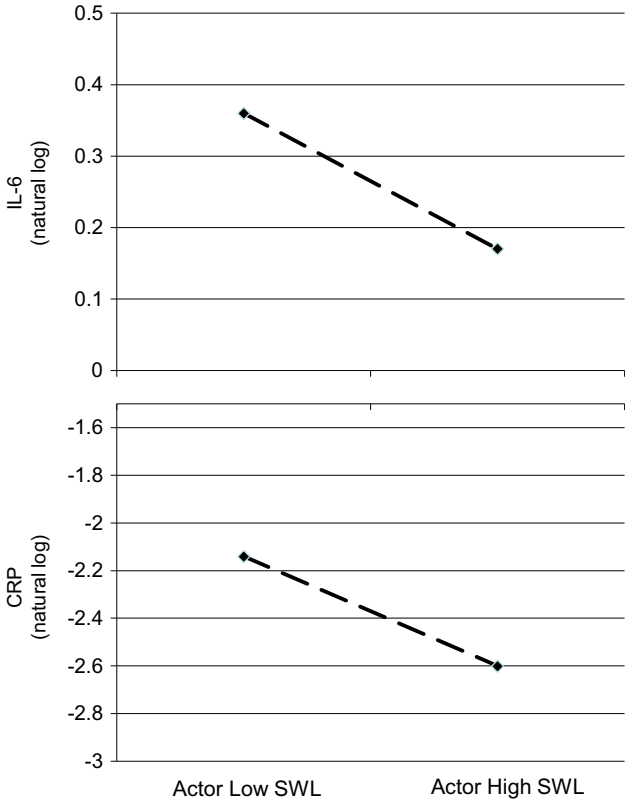

Fig. 1 Predicted IL-6 (top panel) and CRP (bottom panel) as a function of actor satisfaction with life (SWL) one SD below and above the mean

life satisfaction and mortality link. In one of the first studies, Hamer and Chida (2011) found that life satisfaction predicted lower CRP levels in the Scottish Health Survey (also see Nowakowski, 2014). However, the population-based Kuopio Depression Study did not find life satisfaction to be significantly related to either IL-6 or CRP, although it was related to higher levels of the anti-inflammatory adipokine adiponectin (Rissanen et al., 2013). Although more work is needed using a broader panel of inflammatory markers, results of the current study are important because CRP and IL-6 are robust predictors of future cardiovascular risk (Bisoendial et al., 2010; Libby et al., 2002).

The mechanisms responsible for the actor–partner pattern of results obtained in this study will require future work. Life satisfaction has been proposed as a possible causal factor in determining health (Boehm & Kubzansky, 2012). Health behaviors are considered one pathway by which life satisfaction may exert its protective effects. Mediation analyses did not identify health behaviors as a major determinant, and other (currently untested) pathways, such as lower stress exposure or reactivity, may be examined further (Hawkley & Cacioppo, 2004). Alternatively, reverse causality, in which elevated inflammation drives lower satisfaction, remains a theoretical possibility although this would seem less plausible in this cohort of relatively healthy adults. Finally, the association may also reflect a common underlying determinant. For example, twin studies have shown that much individual variance in life satisfaction is due to genetic factors, and it is possible that inflammation and life satisfaction share common genetic determinants, as for example has indeed been identified for the link between inflammation and depression (Bufalino et al., 2013). An initial study did find that a polymorphism in the serotonin transporter gene was related to life satisfaction (De Neve, 2011); however, this association was not replicated in a larger sample (De Neve et al., 2012). Interestingly, polymorphisms in the serotonin transporter gene have been linked to inflammation (Fredericks et al., 2010).

It is possible that these data were strongest for actor influences because life satisfaction taps into chronically accessible information across several important dimensions of life (Diener et al., 2013). For instance, general life satisfaction is correlated with domain-specific life satisfaction regarding relationships/marriage, health, and work (Zou et al., 2013). These data appear consistent with analyses showing that marital satisfaction did not mediate the association between actor life satisfaction and inflammation. Of course, these data do not imply that specific domains of satisfaction are unimportant but that their influence is likely to be smaller compared to a more general index of life satisfaction. Future work which models the separate and combined influences of these domains on general life satisfaction using larger sample sizes would be important to test these hypotheses.

The lack of partner influences was nevertheless surprising in light of recent relationship models of health that suggest partners' interpersonal exchanges (e.g., support, negativity, caregiving) have downstream consequences for biomarkers of health such as inflammation (Pietromonaco et al., 2013; Reed et al., 2013). Studies that model important social transitions specific to romantic relationships (e.g., having children) might identify stronger links between partner levels of life satisfaction, relationship quality, and subsequent biological health (Dyrdal et al., 2011). It is also possible that partner influences were weaker given this study examined relatively healthy participants. Individuals with chronic conditions (e.g., cancer, diabetes) rely on the spouse more heavily for support and assistance given the myriad of medical and adjustment issues they face (Berg & Upchurch, 2007). The greater use of dyadic coping in such chronic disease populations might reveal stronger evidence for partner influences of life satisfaction on inflammation. Finally, a speculative reason why partner effects were not found might be related to the observation of twin studies (Bartels & Boomsma, 2009).

These studies suggest that genes and non-shared experiences explain by far most of the variance in life satisfaction, and the shared environment between siblings (e.g., family life) had a negligible contribution (Bartels, 2015; Bartels & Boomsma, 2009). Extrapolating, this may imply that the shared family/marital environment in adulthood may likewise be a modest determinant of life satisfaction and any down-stream effects (e.g., inflammation).

There are several important limitations of the present study. Although important as an outcome, inflammation is only one of several relevant biological mediators of disease (Uchino et al., 2007). Other studies do suggest dyadic links to cortisol in couples during lab-based interactions and daily life (Powers et al., 2006; Saxbe & Repetti, 2010). Thus, future work will be needed to model dyadic influences of life satisfaction across a number of conceptually-appropriate biological mechanisms. The study also used a primarily White sample. This is an important limitation because ethnicity/race is related to how one views the self in relation to others which is salient in a dyadic context (Markus & Kitayama, 2010). Future work that directly utilizes a more diverse sample will be needed to examine the generalizability of these findings. Finally, the study sample was relatively healthy with limited variability on the health behavior measures. This might have decreased the power of the statistical mediation tests so future research will be needed to address this issue. Despite these limitations, this study advances the literature by showing that actor influences on CRP and IL-6 are stronger then partner influences, and that inflammation is one important biological mechanisms potentially linking actors' life satisfaction to health outcomes.

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Compliance with ethical standards

Conflict of interest Bert N. Uchino, Robert G. Kent de Grey, Sierra Cronan, Timothy W. Smith, Ed Diener, Jos Bosh and Samantha Joel declare that they have no conflicts of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

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