

## Perceived partner responsiveness alters the association between marital distress and well-being in dementia spousal caregivers

Vincent D. Lai<sup>a,\*</sup>, Jensine Paoletti-Hatcher<sup>a</sup>, E. Lydia Wu-Chung<sup>a</sup>, Itee Mahant<sup>a</sup>, Daniel L. Argueta<sup>a</sup>, Kelly N. Brice<sup>a</sup>, Bryan T. Denny<sup>a</sup>, Charles Green<sup>b</sup>, Luis D. Medina<sup>c</sup>, Paul E. Schulz<sup>d</sup>, Jennifer M. Stinson<sup>e</sup>, Cobi J. Heijnen<sup>a</sup>, Christopher P. Fagundes<sup>a,f,g</sup>

<sup>a</sup> Department of Psychological Sciences, Rice University, United States

<sup>b</sup> Department of Pediatrics, McGovern Medical School, United States

<sup>c</sup> Department of Psychology, University of Houston, United States

<sup>d</sup> Department of Neurology, McGovern Medical School, United States

<sup>e</sup> Department of Psychiatry, Cambridge Health Alliance, United States

<sup>f</sup> Department of Psychiatry, Baylor College of Medicine, United States

<sup>g</sup> Department of Behavioral Science, MD Anderson Cancer Center, United States

### ARTICLE INFO

#### Keywords:

Marital distress  
Perceived partner responsiveness  
Depressive symptoms  
Proinflammatory cytokine production  
Dementia spousal caregivers

### ABSTRACT

Caregivers for spouses with Alzheimer's disease and related dementias (ADRD) experience drastic changes in the marital relationship that may put them at risk for worsening well-being. Perceived partner responsiveness, or feeling cared for, understood, and appreciated by one's spouse, may help mitigate these effects. In this study, we investigated the associations between marital distress, perceived partner responsiveness, and psychological and physiological well-being indicators among ADRD spousal caregivers.

**Method:** A sample of 161 caregivers provided blood samples and completed self-report measures of marital distress, perceived partner responsiveness, and depressive symptoms. We tested hypotheses in our sample cross-sectionally based on two theoretical frameworks.

**Results:** Testing the marital discord model of depression, caregivers who reported greater marital distress also reported more depressive symptoms, and this association was stronger as participants reported lower perceived partner responsiveness. Caregivers who reported greater marital distress exhibited elevated proinflammatory cytokine production by in vitro lipopolysaccharide (LPS)-stimulated peripheral blood leukocytes at low levels of perceived partner responsiveness, but not mean or high levels. Testing the vulnerability-stress-adaptation model, caregivers who reported more depressive symptoms also reported greater marital distress. Further, caregivers who exhibited elevated LPS-stimulated proinflammatory cytokine production reported greater marital distress at mean and high levels of perceived partner responsiveness, but not low levels. These patterns of results held even when accounting for the dementia stage and reported hours of caregiving per day.

**Discussion:** This study's findings contribute to the body of research examining interpersonal factors that shape health and well-being among the caregiver population.

### 1. Introduction

For many adults, marital relationships are one of the central relationships in life; spouses constitute a significant source of social, emotional, and financial support [1]. On average, married people are healthier and live longer than people who are single, divorced, or widowed [2,3]. However, there are variations in the quality of marriages; unhappy, conflict-laden marriages may be less beneficial or even

harmful to well-being. Indeed, unhappier marriages are associated with worse self-reported health and a greater mortality risk than happier marriages [4].

Caregiving for a spouse with Alzheimer's disease or a related dementia (ADRD) is an immensely stressful experience associated with drastic changes in the marital relationship. With the onset and progression of ADRD, caregivers report disruptions in the relationship, including a lack of intimacy, difficulty feeling connected, changing roles

\* Corresponding author. Rice University, 6100 Main Street, Houston, TX, 77005, United States.

E-mail address: [Vincent.D.Lai@rice.edu](mailto:Vincent.D.Lai@rice.edu) (V.D. Lai).

<https://doi.org/10.1016/j.cpnec.2024.100271>

Received 28 April 2024; Received in revised form 10 October 2024; Accepted 10 October 2024

Available online 18 October 2024

2666-4976/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

and identities, and uncertainties surrounding the diagnosis and relationship [5,6]. Among interpersonal factors that may be important to the caregiving experience, we focus on the potential role of perceived partner responsiveness in altering the associations between marital distress and well-being among caregivers.

### 1.1. Marital distress and well-being

*Marital distress* entails negative evaluations of one's marital relationship, such as difficulties with communicating and problem-solving, an inability to accept each other's differences, and feeling dissatisfied with the relationship [7,8]. The associations between marital distress and worsening psychological well-being outcomes have been well-documented among married adults [9]. Experiencing greater marital distress is associated with more symptoms of depression [10], a greater risk for mental health problems [11], and greater utilization of mental health care services [12]. In the specific context of ADRD spousal caregiving, experiencing marital distress may increase susceptibility to the adverse effects of caregiving on psychological well-being among caregivers. For instance, among caregivers, greater dissatisfaction with the marital relationship is associated with more depressive symptoms [13] and more significant caregiver burden [14]. Poor communication between care partners can also contribute to more severe depressive symptoms [15].

Experiencing marital distress may also be associated with worsening physiological well-being. *Inflammation* is an immunological response to physical injury or infection that promotes the production of proinflammatory cytokines, which recruit immune cells, facilitating, among other things, pathogen destruction and wound healing [16]. Acute, local inflammation in response to injury or infection can be beneficial; however, prolonged, low-grade inflammation is associated with harmful impacts on health, including premature aging, increased mortality risk, and chronic diseases and conditions of older adulthood [16,17]. Importantly, interpersonal stressors, such as receiving low social support or being in hostile, conflict-filled relationships, are associated with elevated proinflammatory cytokine production [16]. Among married adults, lower marital quality (i.e., lower levels of social support and higher levels of strain in the relationship) is associated with higher levels of proinflammatory cytokine production [18]. In the context of caregiving, ADRD spousal caregivers, compared to non-caregivers, exhibit greater age-related elevations in proinflammatory cytokine production [19]; stressors associated with the relationship may exacerbate elevations in proinflammatory cytokine production.

### 1.2. Perceived partner responsiveness

Although caregiving for a spouse with ADRD can be detrimental to well-being, some caregivers may fare better than others. One factor that might be important to caregivers' well-being is *perceived partner responsiveness*, or the extent to which individuals feel cared for, understood, and appreciated by their romantic partners [20]. Greater perceived partner responsiveness is associated with more affectionate touch [21], fewer sleep problems [22], and greater longitudinal increases in eudaimonic (associated with purpose and meaning in life) well-being [23]. Furthermore, prior studies have considered perceived partner responsiveness as an important interpersonal process that may buffer the detrimental impacts of stress on functioning and well-being; perceived partner responsiveness has been shown to attenuate the effects of depressive symptoms and stress on marital adjustment [24] and the impact of loneliness, financial strain, and stress on relationship quality [25]. In this study, we utilize a similar conceptual and analytical approach by considering perceived partner responsiveness as an important moderator of the associations between marital distress and well-being among ADRD spousal caregivers.

Although less empirical work examines perceived partner responsiveness's role in caregiving relationships, some prior studies suggest that

caregivers and care recipients may benefit from partners' responsiveness [26,27]. For instance, care recipients who report greater responsiveness from their caregiver partners also report being more satisfied with the relationship [26]. More open communication between care partners is associated with greater perceived responsiveness, which, in turn, is associated with more intimacy [27]. However, these studies primarily focus on contexts of general informal caregiving or spousal caregiving for other conditions (e.g., Parkinson's disease), and the role of perceived partner responsiveness in ADRD spousal caregiving relationships remains largely unexplored. People with dementia experience behavioral changes over time that can impede their ability to be responsive to caregiving partners [28]; however, caregivers' perceptions of closeness with their partner also influence disease progression and thus warrant further exploration [29]. Furthermore, little work has been done to assess the impacts of perceived partner responsiveness on physiological well-being. One study found evidence of a beneficial effect of perceived partner responsiveness on waking cortisol levels and diurnal cortisol slopes [30].

### 1.3. The marital discord model of depression

A growing body of research documents evidence of the effects of marital distress on well-being. The *marital discord model of depression* is a useful theoretical framework that describes the influence of difficulties in marital relationships on depressive symptoms through hostile and unsupportive behaviors [31]. Much empirical research has focused on the associations between marital distress and depressive symptoms; greater marital distress is associated with more depressive symptoms cross-sectionally and also predicts later increases in depressive symptoms [9]. Some work has also been done to expand the marital discord model of depression to consider the impacts of marital distress on physiological well-being outcomes. Hostile interactions between spouses, an important indicator of marital distress, predict higher levels of inflammatory markers and slower wound healing, compared to non-hostile interactions [32]. However, much fewer studies have tested the marital discord model of depression in the context of caregiving. Prior research has also not yet examined the potential role of perceived partner responsiveness in influencing the link between marital distress and well-being outcomes.

Thus, in this study, we sought to test and extend the marital discord model of depression by investigating the role of perceived partner responsiveness in influencing both psychological (i.e., depressive symptoms) and physiological (i.e., inflammation) well-being outcomes among ADRD spousal caregivers. We expected that greater marital distress would be associated with poorer psychological and physiological well-being and that these associations would depend on levels of perceived partner responsiveness. Specifically, we hypothesized that greater marital distress would be positively associated with depressive symptoms (H1a) and proinflammatory cytokine production by in vitro lipopolysaccharide (LPS)-stimulated peripheral blood leukocytes (H1b). Focusing on the interaction between marital distress and perceived partner responsiveness, we expected that experiencing low levels of perceived partner responsiveness would exacerbate the potential adverse effects of marital distress on well-being. Thus, we hypothesized that caregivers who report lower levels of perceived partner responsiveness, relative to those who report higher levels of perceived partner responsiveness, would exhibit stronger associations between marital distress and depressive symptoms (H2a) and LPS-stimulated proinflammatory cytokine production (H2b).

### 1.4. The vulnerability-stress-adaptation model

Although the effects of marital quality on well-being is well known, prior studies have also provided evidence for a bidirectional relationship, such that well-being may also have important influences on later marital outcomes. Based on the vulnerability-stress-adaptation (VSA)

model [33], enduring vulnerabilities are relatively stable characteristics that each spouse brings into the marriage. When confronted with stressful events, these personal characteristics interact with adaptive processes unfolding within the marriage to shape evaluations of the marital relationship over time. Indeed, existing vulnerabilities and stressors may influence someone's perceptions of and behaviors toward their spouse [34]. Prior studies have focused on depressive symptoms as an enduring vulnerability, such that spouses experiencing more symptoms of depression also report being less satisfied with their marriages and experience declining marital adjustment over time, relative to those reporting less symptoms of depression [24,35]. We might also expect that inflammation may be a potential enduring vulnerability; heightened inflammation may influence social behaviors in ways that contribute to negative interactions and experiences with one's spouse. For instance, more elevated levels of proinflammatory cytokine production in response to an acute inflammatory challenge have been shown to induce greater feelings of social disconnection from others and a more depressed mood compared to less elevated cytokine production [36].

In the context of spousal caregiving (a significant stressor), caregivers' personal vulnerabilities may interact with adaptive processes in the caregiving relationship to influence caregivers' evaluations of their marital relationships. In line with the VSA model, we also investigated the potential role of depressive symptoms and LPS-stimulated proinflammatory cytokine production as vulnerabilities shaping marital distress among caregivers. We also consider perceived partner responsiveness as an adaptive process within the marriage that may influence the effects of caregiver well-being on marital distress. We expected that poorer caregiver well-being would be associated with greater marital distress and that these associations would depend on levels of perceived partner responsiveness. Specifically, we hypothesized that more depressive symptoms (H3a) and greater LPS-stimulated proinflammatory cytokine production (H3b) would be positively associated with marital distress. We also hypothesized that caregivers who report higher levels of perceived partner responsiveness, relative to those who report lower levels, would exhibit weaker associations between depressive symptoms (H4a) or LPS-stimulated proinflammatory cytokine production (H4b) and marital distress.

## 2. Methods

### 2.1. Participants

A sample of 161 ADRD spousal caregivers (see Table 1 for sample characteristics) was recruited as part of a larger longitudinal cohort study investigating factors influencing risk and resilience to the adverse effects of dementia caregiving on physical health. Participants were recruited from the community through approved access to patient portals and clinic schedules, referrals from treating physicians, newspaper advertisements, social media postings, and flyers. The local Institutional Review Board approved all recruitment strategies.

Interested participants completed a screening form over the phone and were considered eligible if they self-identified as the primary person caring for their spouse with dementia, devoted at least 4 h daily to caregiving, and had been married (or in a long-term committed partnership) for at least three years. Participants were excluded if they had Stage IV cancer. Participants completed medical release forms allowing for a dementia diagnosis to be confirmed by patients' care providers. All participants consented to the study procedures.

### 2.2. Procedure

Participants completed in-person visits led by trained research assistants and staff either in the laboratory or at their homes. Prior to their visits, participants were asked to follow dietary and behavioral guidelines to minimize potential confounds to biological data. Participants

**Table 1**  
Descriptive statistics for study sample.

Variable	<i>M</i> ( <i>SD</i> ) or Number (%)
Age	71.27 (7.98)
Gender	
Male	45 (27.95)
Female	116 (72.05)
Race	
White	134 (83.23)
Black or African American	20 (12.42)
Asian	4 (2.48)
Other	3 (1.86)
Education	
Less Than 7 Years	1 (0.63)
High School Graduate	20 (12.66)
Up to 3 Years of College	21 (13.29)
At Least 3 Years of College	28 (17.72)
Graduate or Professional Training	88 (55.70)
BMI	29.15 (6.44)
Inflammation-related medications	
No	49 (31.21)
Yes	108 (68.79)
Marital distress	11.57 (5.21)
Perceived partner responsiveness	9.63 (2.30)
Depressive symptoms	11.55 (9.65)

*Note.* *M* and *SD* are used to represent mean and standard deviation, respectively, and are reported for all continuous variables.

were also asked to refrain from consuming alcohol 48 h before their visits, as well as caffeine and high-fat food the morning of their visit. Research assistants provided reminders of these guidelines within 1–2 business days before the visit. Participants completed self-report questionnaires, health assessments, and blood draws during the in-person visit. Research assistants obtained height and weight measurements. Participants received compensation upon completion of their visits.

### 2.3. Measures

#### 2.3.1. Marital distress

The 4-item Couple Satisfaction Index (CSI-4) was used to measure participants' general evaluations of their relationship with their partners [7]. Respondents reported the degree of happiness of their relationship on a 0 (*Extremely unhappy*) to 6 (*Perfect*) scale and answered three questions about their relationship (e.g., "How rewarding is your relationship with your partner?") on a 0 (*Not at all*) to 5 (*Completely*) scale. The four items demonstrated excellent internal consistency ( $\alpha = .91$ ); for the purpose of this study, the items were coded such that higher scores indicated greater marital distress and lower scores indicated lower marital distress.

#### 2.3.2. Perceived partner responsiveness

Three items revised from the positive spouse interaction items from Schuster et al. [37] were used as a measure of perceived partner responsiveness. These items have been used in previous studies of perceived partner responsiveness [23] and correspond to the components of perceived partner responsiveness described in the literature [20]. Respondents indicated the extent to which they felt certain ways about their spouses (e.g., "How much does your spouse or partner really care about you?") on a scale from 1 (*Not at all*) to 4 (*A lot*). The three items demonstrated good internal consistency ( $\alpha = .80$ ) and were summed to obtain an overall perceived partner responsiveness score, where higher scores indicated greater perceived partner responsiveness and lower scores indicated lower perceived partner responsiveness.

#### 2.3.3. Depressive symptoms

The Center for Epidemiologic Studies Depression Scale (CES-D) was used as a measure to assess participants' depressive symptoms [38]. Respondents indicated the extent to which they felt certain ways in the

past week (e.g., “I was bothered by things that usually don’t bother me”) on a 0 (*Rarely or none of the time*) to 3 (*Most or all of the time*) scale. The 20 items, after reverse-scoring the appropriate items, demonstrated excellent internal consistency ( $\alpha = .91$ ) and were summed to obtain an overall depressive symptomatology score, where higher scores indicated greater depressive symptomatology and lower scores indicated less depressive symptomatology.

### 2.3.4. Proinflammatory cytokine production by *In vitro* lipopolysaccharide-stimulated peripheral blood leukocytes

To assess participants’ levels of proinflammatory cytokine production by *in vitro* LPS-stimulated peripheral blood leukocytes, we performed whole blood cultures stimulated with LPS to investigate the capacity of monocytes, a type of white blood cell, to produce the cytokines mentioned below in response to an immunological challenge. The proinflammatory cytokines assessed included interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF- $\alpha$ ), and interleukin-1 $\beta$  (IL-1 $\beta$ ). LPS-stimulated proinflammatory cytokine production was assessed by heparinized whole blood diluted 1:10 with RPMI-1640 (Gibco) and stimulated with 1 ng/mL LPS (Sigma) at 37 °C and 5 % CO<sub>2</sub> for 16–18 h. Supernatants were collected after 16–18 h of culture and stored at –80 °C until analyzed using a multiplex cytokine assay according to the manufacturer’s instructions (Millipore Sigma).

As multiple proinflammatory cytokines serve as indicators of inflammatory signaling, we created a composite index of proinflammatory markers to minimize Type I error associated with repeated hypothesis testing of individual biomarkers. Composite variables are commonly used for controlling Type I error rate, such as when sample size is insufficient for testing multiple comparisons, and for organizing highly correlated variables into a more meaningful construct [39]. This approach has been established and used in prior research [40,41]. For each individual cytokine, *z*-scores were calculated from natural log-transformed values and averaged to create a composite inflammatory index for each participant. The composite, which included the proinflammatory cytokines IL-6, TNF- $\alpha$ , and IL-1 $\beta$ , had a Cronbach’s alpha of 0.86. The composite inflammatory index was used in all primary analyses, and cytokines were analyzed individually for analyses with the composite index that were significant.

### 2.3.5. Covariates

Demographic factors, body mass index (BMI), and inflammation-related medications were also included in statistical models as covariates, which were selected a priori based on standard recommendations in the field of psychoneuroimmunology [42]. Participants provided self-reports of their age, gender, and the number of hours spent caregiving per day. BMI was computed as participants’ weight in kilograms divided by their height in meters squared. Inflammation-related medication (i.e., aspirin, statins, hypertensive medications, and/or antidepressants) use was coded as a binary variable. Dementia diagnosis was obtained from care providers’ records. Participants completed the Charlson Comorbidity Index [43], from which a combined score was obtained as a total of participants’ comorbid conditions which have been weighted.

## 2.4. Statistical analyses

An a priori power analysis that was conducted prior to the study using the *pwr* package in R (v1.3.0) [44] indicated that a minimum of 114 participants was required in order to have 80 % power for detecting a medium-sized effect ( $f^2 = 0.15$ ) when employing the traditional 0.05 criterion of statistical significance. Thus, the obtained sample size was sufficient to detect the study hypotheses. We assessed descriptive statistics and natural log-transformed proinflammatory markers, as they were positively skewed. Prior to conducting linear regression analyses, we checked assumptions of linearity, normality, homoscedasticity, and multicollinearity. All assumptions were met.

All analyses were performed using the R Statistical Software (v4.3.1) [45]. In order to retain as much information as possible from the data set, we accounted for missing data by using full-information maximum likelihood, which estimates parameters based on the observed data [46]. Full-information likelihood is superior to listwise deletion for handling missing data, is robust against non-normality, and performs well when data are missing at random, even with low sample sizes [47]. All models were fit using full-information maximum likelihood with the *lavaan* (v0.6.16) [48] and *semTools* packages (v0.5.6) [49] in R. Using this approach, the *F*-test is not appropriate. Thus, all analyses presented in the following sections were also conducted using ordinary least squares regression with listwise deletion. This approach has been previously used in prior research [50]. Based on this procedure, the significant relationships presented in the following sections were unchanged.

To test our study hypotheses based on the marital discord model of depression, we conducted multiple linear regressions to assess the relationships between marital distress, perceived partner responsiveness, and depressive symptoms (H1a and 2a) or the composite inflammatory index (H1b and 2b). To test our study hypotheses based on the VSA model, we also conducted multiple linear regressions to assess the relationships between perceived partner responsiveness, depressive symptoms (H3a and 4a) or the composite inflammatory index (H3b and 4b), and marital distress. All models included age, gender, race, and education as covariates. Models with the composite inflammatory index as the outcome variable also included BMI and inflammation-related medications as covariates. In addition, exploratory analyses were conducted post hoc for primary analyses with the composite inflammatory index as the outcome variable that were significant. We performed these analyses using the individual proinflammatory cytokines.

## 3. Results

Descriptive statistics for the sample and variables of interest are reported in Table 1; zero-order correlations among study variables of interest are reported in Table 2. Regression results for all primary analyses are reported in Tables 3 and 4. Scatter plots are provided for the associations between marital distress and perceived partner responsiveness (Supplementary Fig. 1), depressive symptoms and perceived partner responsiveness (Supplementary Fig. 2), and the composite inflammatory index and perceived partner responsiveness (Supplementary Fig. 3) for reference.

### 3.1. Primary analyses

#### 3.1.1. The marital discord model of depression

To assess the link between marital distress and well-being in caregivers based on the marital discord model of depression (Table 3), we first conducted multiple linear regressions to assess the associations between marital distress and depressive symptoms (1a) and the composite inflammatory index (1b). In the model testing Hypothesis 1a, greater marital distress was significantly associated with more depressive symptoms ( $p < .001$ ), such that those who reported greater marital distress also reported more depressive symptoms compared to those reporting less marital distress. In the model testing Hypothesis 1b, marital distress was not significantly associated with levels of the composite inflammatory index ( $p = .06$ ).

We then conducted multiple linear regressions to assess the associations between marital distress, perceived partner responsiveness, and depressive symptoms (2a) and the composite inflammatory index (2b).

In the model testing Hypothesis 2a, the interaction term representing marital distress and perceived partner responsiveness was significantly associated with depressive symptoms ( $p = .021$ ). In the analysis of the simple slopes, as shown in Fig. 1, we found that greater marital distress was significantly associated with more depressive symptoms among caregivers reporting low ( $-1$  SD below average;  $b = 1.05$ ,  $SE = 0.22$ ,  $p < .001$ ), mean ( $b = 0.76$ ,  $SE = 0.18$ ,  $p < .001$ ), and high ( $+1$  SD above

**Table 2**  
Zero-order correlations among primary study variables and covariates.

Variable	1	2	3	4	5	6	7	8	9
1. Marital distress									
2. Perceived partner responsiveness	-0.66**								
3. Depressive symptoms	0.40**	-0.24**							
4. Composite inflammatory index	0.21*	-0.16	0.12						
5. IL-6	0.23*	-0.17	0.11	0.91**					
6. TNF-α	0.16	-0.09	0.16	0.88**	0.70**				
7. IL-1β	0.17	-0.18	0.04	0.88**	0.71**	0.64**			
8. Age	-0.06	0.11	-0.12	0.17	0.14	0.13	0.18*		
9. Education	-0.02	-0.06	-0.05	0.03	-0.06	0.06	0.07	0.09	
10. BMI	0.00	-0.07	0.13	0.15	0.16	0.08	0.17	-0.11	-0.22**

Note. \* $p < .05$ .  
\*\* $p < .01$ .

**Table 3**  
Results of regressions predicting depressive symptoms and the composite inflammatory index.

Predictors	Depressive Symptoms		Composite Inflammatory Index	
	<i>b</i> (SE)	<i>b</i> (SE)	<i>b</i> (SE)	<i>b</i> (SE)
Age	-0.14 (0.09)	-0.14 (0.09)	0.02 (0.01)*	0.02 (0.01)*
Sex <sup>a</sup>	-0.59 (1.65)	-0.76 (1.63)	-0.06 (0.19)	-0.06 (0.18)
Race				
White	-0.25 (11.15)	-0.55 (10.96)	0.52 (0.60)	0.46 (0.60)
Black or African American	4.79 (11.34)	4.57 (11.14)	0.72 (0.69)	0.70 (0.68)
Asian	-1.43 (9.94)	-1.39 (9.76)	0.89 (0.67)	0.86 (0.66)
Other	-6.28 (9.98)	-5.96 (9.80)	0.21 (0.70)	0.23 (0.69)
Education	-0.47 (0.65)	-0.38 (0.64)	0.01 (0.08)	0.03 (0.08)
BMI			0.01 (0.01)	0.02 (0.01)
Inflammation-related medications <sup>b</sup>			0.23 (0.20)	0.2 (0.20)
Marital distress	0.76 (0.19)***	1.97 (0.55)***	0.04 (0.02)	0.17 (0.07)*
Perceived partner responsiveness	0.24 (0.41)	2.01 (0.87)*	-0.01 (0.05)	0.18 (0.10)
Marital distress x Perceived partner responsiveness		-0.13 (0.05)*		-0.01 (0.01)*

Note.  
\*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .  
<sup>a</sup> Sex is coded so 0 = male and 1 = female.  
<sup>b</sup> Inflammation-related medications are coded such that 0 = Not taking medications and 1 = taking medications.

average;  $b = 0.47$ ,  $SE = 0.22$ ,  $p = .035$ ) levels of perceived partner responsiveness. At low, mean, and high levels of perceived partner responsiveness, those who reported greater marital distress also reported more depressive symptoms, compared to those who reported less marital distress.

In the model testing Hypothesis 2b, the interaction term representing marital distress and perceived partner responsiveness was significantly associated with the composite inflammatory index ( $p = .046$ ). In the simple slopes analysis, as shown in Fig. 2, we found that greater marital distress was significantly associated with higher levels of the composite inflammatory index among caregivers reporting low levels of perceived partner responsiveness ( $b = 0.07$ ,  $SE = 0.03$ ,  $p = .007$ ). At low levels of perceived partner responsiveness, those who reported greater marital distress also exhibited elevated LPS-stimulated proinflammatory cytokine production, compared to those who reported less marital distress. However, marital distress was not significantly associated with the

**Table 4**  
Results of regressions predicting marital distress.

Predictors	Marital Distress			
	<i>b</i> (SE)	<i>b</i> (SE)	<i>b</i> (SE)	<i>b</i> (SE)
Age	0.03 (0.04)	0.04 (0.04)	0.01 (0.04)	0 (0.04)
Sex <sup>a</sup>	1.74 (0.67)*	1.77 (0.67)**	1.64 (0.71)*	1.35 (0.71)
Race				
White	0.11 (4.65)	0.33 (4.63)	-0.66 (4.95)	-1.2 (4.85)
Black or African American	0.78 (4.72)	1.19 (4.71)	0.59 (5.08)	0.08 (4.97)
Asian	0.42 (4.14)	0.69 (4.13)	-0.52 (4.43)	-0.81 (4.33)
Other	-1.01 (4.16)	-0.91 (4.14)	-2.57 (4.4)	-2.51 (4.29)
Education	-0.22 (0.27)	-0.21 (0.27)	-0.38 (0.29)	-0.4 (0.29)
BMI			-0.05 (0.05)	-0.07 (0.05)
Inflammation-related medications <sup>b</sup>			-1 (0.73)	-1.13 (0.71)
Perceived partner responsiveness	-1.38 (0.13)***	-1.55 (0.19)***	-1.47 (0.14)***	-1.44 (0.13)***
Depressive symptoms	0.13 (0.03)***	0.03 (0.09)		
Depressive Symptoms x Perceived partner responsiveness			0.01 (0.01)	
Composite inflammatory index			0.77 (0.4)	4.42 (1.53)**
Composite inflammatory index x Perceived partner responsiveness				-0.37 (0.15)*

Note. \* $p < .05$ .  
\*\* $p < .01$ .  
\*\*\* $p < .001$ .  
<sup>a</sup> Sex is coded so 0 = male and 1 = female.  
<sup>b</sup> Inflammation-related medications are coded such that 0 = Not taking medications and 1 = taking medications.

composite inflammatory index among caregivers reporting average ( $p = .08$ ) and high ( $p = .86$ ) levels of perceived partner responsiveness.

### 3.1.2. The vulnerability-stress-adaptation model

To assess the link between enduring vulnerabilities and marital distress in caregivers based on the VSA model (Table 4), we conducted multiple linear regressions to assess the associations between depressive symptoms (H3a) or the composite inflammatory index (H3b) and marital distress. In the model testing Hypothesis 3a, more depressive symptoms were associated with greater marital distress ( $p < .001$ ), such that those who reported more depressive symptoms also reported greater marital distress compared to those reporting less depressive

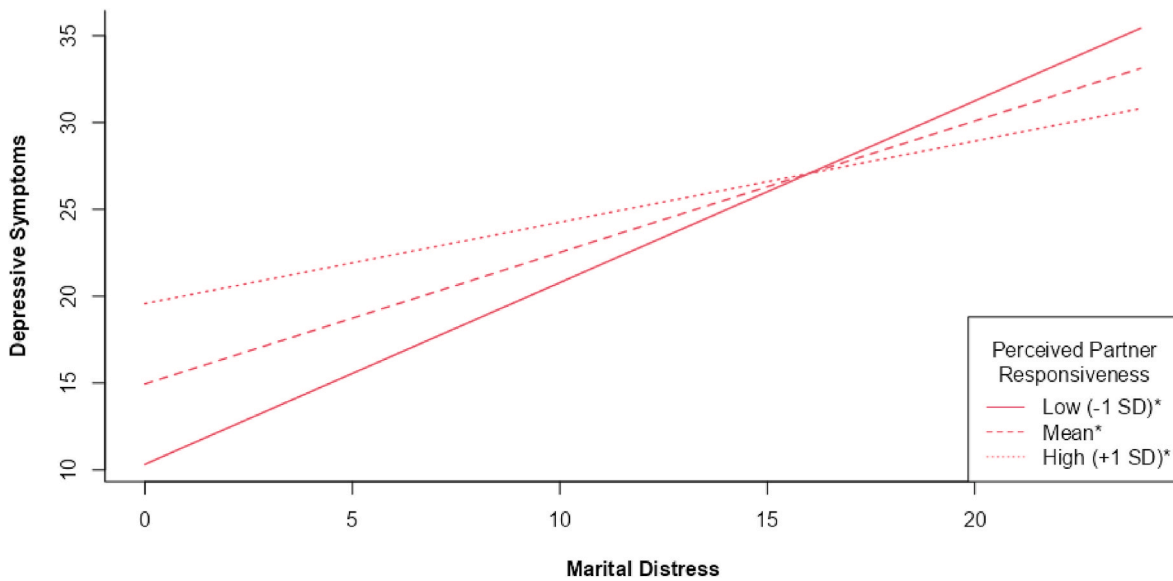


Fig. 1. Interaction of the Effects of Marital Distress and Perceived Partner Responsiveness on Depressive Symptoms Note. \* indicates significant simple slopes.

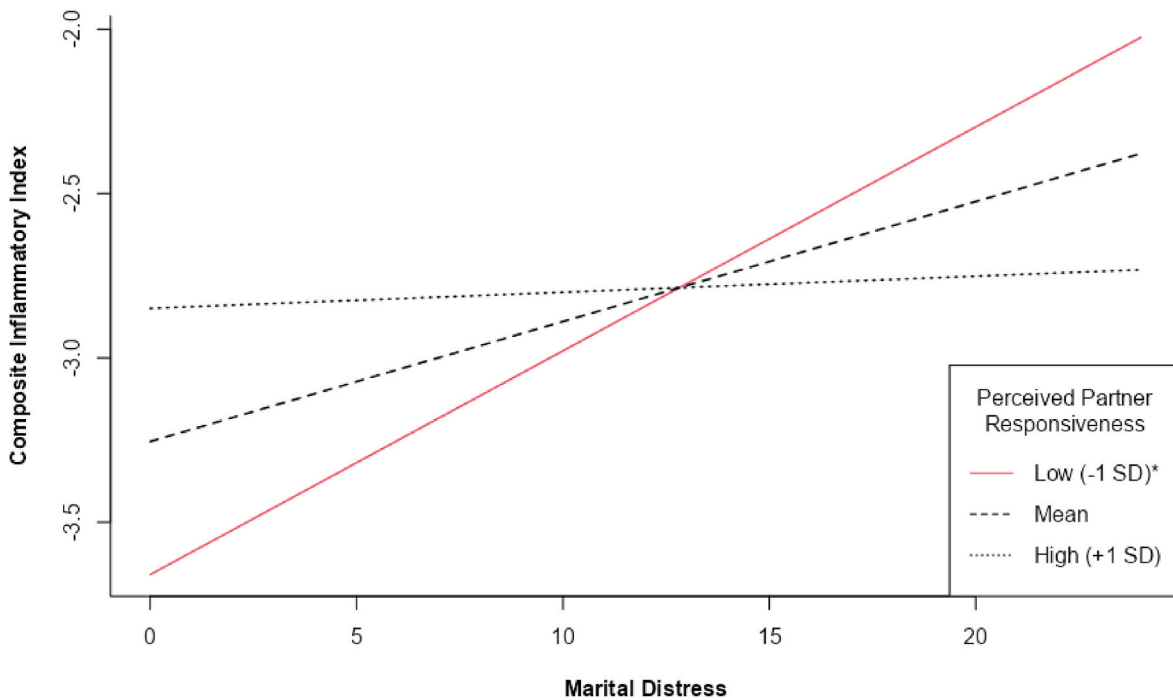


Fig. 2. Interaction of the Effects of Marital Distress and Perceived Partner Responsiveness on the Composite Inflammatory Index Note. \* indicates significant simple slopes.

symptoms. In the model testing Hypothesis 3b, the composite inflammatory index was not significantly associated with marital distress ( $p = .06$ ).

We then conducted multiple linear regressions to assess the associations between depressive symptoms (H4a), the composite inflammatory index (H4b), perceived partner responsiveness, and marital distress.

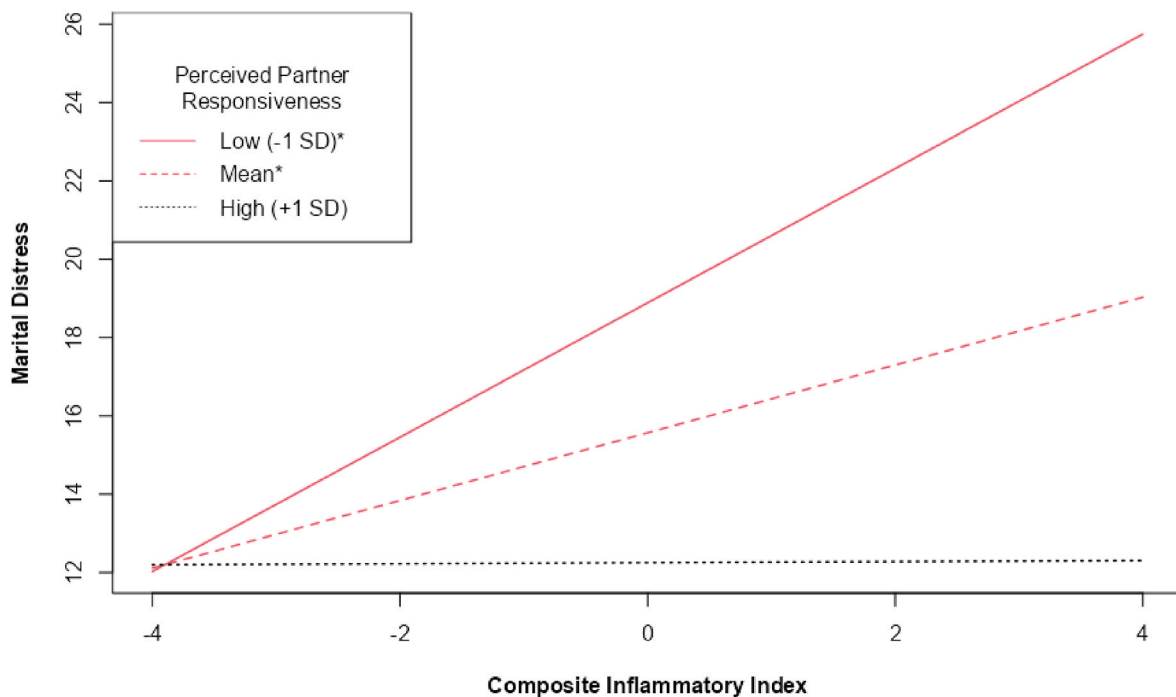
In the model testing Hypothesis 4a, the interaction term representing depressive symptoms and perceived partner responsiveness was not significantly associated with marital distress ( $p = .30$ ).

In the model testing Hypothesis 4b, the interaction term representing the composite inflammatory index and perceived partner responsiveness was significantly associated with marital distress ( $p = .014$ ). In the simple slopes analysis, as shown in Fig. 3, we found that higher levels of

the composite inflammatory index were associated with greater marital distress among caregivers reporting low ( $b = 1.72, SE = 0.55, p = .002$ ) and mean ( $b = 0.87, SE = 0.39, p = .028$ ) levels of perceived partner responsiveness. At low and mean levels of perceived partner responsiveness, those who exhibited greater LPS-stimulated proinflammatory cytokine production reported greater marital distress compared to those exhibiting lower cytokine production. The composite inflammatory index was not significantly associated with marital distress at high levels of perceived partner responsiveness ( $p = .98$ ).

### 3.2. Post hoc analyses

All primary analyses were conducted with average number of hours



**Fig. 3.** Interaction of the Effects of the Composite Inflammatory Index and Perceived Partner Responsiveness on Marital Distress Note. \* indicates significant simple slopes.

spent caregiving per day, dementia diagnosis, and caregiver comorbidities as covariates to account for their potential influences on our variables of interest. Based on the results of these models, the significant relationships presented in the previous section were unchanged.

### 3.2.1. The marital discord model of depression

As the interaction term representing marital distress and perceived partner responsiveness was significantly associated with the composite inflammatory index in our analyses testing the marital discord model of depression, we additionally conducted individual analyses with LPS-stimulated IL-6, TNF- $\alpha$ , and IL-1 $\beta$  as outcome variables.

We found that the interaction term representing marital distress and perceived partner responsiveness was significantly associated with levels of LPS-stimulated IL-6 ( $b = -0.01$ ,  $SE = 0.01$ ,  $p = .046$ ). In the simple slopes analysis, we found that greater marital distress was associated with elevated levels of LPS-stimulated IL-6 in caregivers reporting low levels of perceived partner responsiveness ( $b = 0.05$ ,  $SE = 0.02$ ,  $p = .005$ ). At low levels of perceived partner responsiveness, those who reported greater marital distress also exhibited elevated LPS-stimulated IL-6. However, marital distress was not associated with levels of LPS-stimulated IL-6 in caregivers reporting mean ( $p = .06$ ) and high levels of perceived partner responsiveness ( $p = .78$ ).

We also found that the interaction term representing marital distress and perceived partner responsiveness was significantly associated with levels of LPS-stimulated TNF- $\alpha$  ( $b = -0.01$ ,  $SE = 0.01$ ,  $p = .050$ ). In the simple slopes analysis, greater marital distress was associated with elevated levels of LPS-stimulated TNF- $\alpha$  among caregivers reporting low levels of perceived partner responsiveness ( $b = 0.04$ ,  $SE = 0.02$ ,  $p = .012$ ). At low levels of perceived partner responsiveness, those who reported greater marital distress also exhibited elevated LPS-stimulated TNF- $\alpha$ . However, marital distress was not associated with levels of LPS-stimulated TNF- $\alpha$  among caregivers reporting mean ( $p = .12$ ) and high ( $p = .98$ ) levels of perceived partner responsiveness.

Finally, we found that the interaction term representing marital distress and perceived partner responsiveness was not significantly associated with levels of LPS-stimulated IL-1 $\beta$  ( $p = .18$ ).

To further probe the significant interaction effects of marital distress

and perceived partner responsiveness on depressive symptoms or the composite inflammatory index, we additionally conducted simple slopes analyses to assess the effects of perceived partner responsiveness on depressive symptoms or the composite inflammatory index at low, mean, and high levels of marital distress.

In the simple slopes analysis with depressive symptoms as the outcome, as shown in [Supplementary Fig. 4](#), we found that greater perceived partner responsiveness was associated with more depressive symptoms among caregivers reporting low levels of marital distress ( $b = 1.21$ ,  $SE = 0.59$ ,  $p = .038$ ). At low levels of a marital distress, caregivers who reported greater perceived partner responsiveness also reported more depressive symptoms, compared to those who reported lower perceived partner responsiveness. Perceived partner responsiveness was not significantly associated with depressive symptoms at mean ( $p = .19$ ) and high ( $p = .82$ ) levels of marital distress.

In the simple slopes analysis with the composite inflammatory index as the outcome, as shown in [Supplementary Fig. 5](#), we found that perceived partner responsiveness was not significantly associated with the composite inflammatory index at low ( $p = .19$ ), mean ( $p = .72$ ), and high ( $p = .29$ ) levels of marital distress.

### 3.2.2. The vulnerability-stress-adaptation model

As the interaction term representing the composite inflammatory index and perceived partner responsiveness was significantly associated with marital distress in our analyses testing the VSA model, we also additionally conducted individual analyses with the interaction term representing perceived partner responsiveness and LPS-stimulated IL-6, TNF- $\alpha$ , and IL-1 $\beta$ , respectively, predicting marital distress.

We found that the interaction term representing LPS-stimulated TNF- $\alpha$  and perceived partner responsiveness was significantly associated with marital distress ( $b = -0.48$ ,  $SE = 0.21$ ,  $p = .025$ ). In the simple slopes analysis, elevated levels of LPS-stimulated TNF- $\alpha$  were associated with greater marital distress among caregivers reporting low levels of perceived partner responsiveness ( $b = 2.05$ ,  $SE = 0.74$ ,  $p = .006$ ). At low levels of perceived partner responsiveness, those who exhibited higher levels of LPS-stimulated TNF- $\alpha$  also reported greater marital distress compared to those exhibiting lower levels of LPS-stimulated TNF- $\alpha$ .

However, levels of LPS-stimulated TNF- $\alpha$  were not significantly associated with marital distress among caregivers reporting mean ( $p = .10$ ) or high ( $p = .84$ ) levels of perceived partner responsiveness.

We also found that the interaction term representing LPS-stimulated IL-1 $\beta$  and perceived partner responsiveness was significantly associated with marital distress ( $b = -0.48$ ,  $SE = 0.21$ ,  $p = .019$ ). In the simple slopes analysis, elevated levels of LPS-stimulated IL-1 $\beta$  were associated with greater marital distress among caregivers reporting low levels of perceived partner responsiveness ( $b = 2.05$ ,  $SE = 0.75$ ,  $p = .007$ ). At low levels of perceived partner responsiveness, those who exhibited higher levels of LPS-stimulated IL-1 $\beta$  also reported greater marital distress compared to those exhibiting lower levels of LPS-stimulated IL-1 $\beta$ . However, levels of LPS-stimulated IL-1 $\beta$  were not significantly associated with marital distress among caregivers reporting mean ( $p = .06$ ) or high ( $p = .79$ ) levels of perceived partner responsiveness.

Finally, we found that the interaction term representing LPS-stimulated IL-6 and perceived partner responsiveness was not significantly associated with marital distress ( $b = -0.46$ ,  $SE = 0.24$ ,  $p = .058$ ).

To further probe the significant interaction effect of the composite inflammatory index and perceived partner responsiveness on marital distress, we additionally conducted a simple slopes analysis to assess the effects of perceived partner responsiveness on marital distress at low, mean, and high levels of the composite inflammatory index.

In the simple slopes analysis, as shown in [Supplementary Fig. 6](#), we found that greater perceived partner responsiveness was associated with lower marital distress among caregivers reporting low ( $b = -1.11$ ,  $SE = 0.20$ ,  $p < .001$ ), mean ( $b = -1.44$ ,  $SE = 0.13$ ,  $p < .001$ ), and high ( $b = -1.77$ ,  $SE = 0.18$ ,  $p < .001$ ) levels of the composite inflammatory index. At low, mean, and high levels of the composite inflammatory index, caregivers who reported greater perceived partner responsiveness also reported less marital distress, compared to those who reported lower perceived partner responsiveness.

#### 4. Discussion

In this study, we examined the influence of perceived partner responsiveness on well-being among caregivers of spouses living with ADRD. We tested hypotheses based on two theoretical frameworks, focusing on the potential bidirectional interplay between marital distress and outcomes of psychological and physiological well-being and how feeling cared for, understood, and appreciated by one's spouse may alter these associations. Drawing from the literature on marital relationships, we surmised that experiencing low perceived partner responsiveness would exacerbate the potential negative consequences of marital distress on well-being among ADRD spousal caregivers; our hypotheses based on the marital discord model of depression stated that caregivers who report lower perceived partner responsiveness should exhibit stronger associations between marital distress and depressive symptoms or LPS-stimulated proinflammatory cytokine production compared to those reporting higher perceived partner responsiveness. Drawing from the VSA model, we reasoned that perceived partner responsiveness may serve as an adaptive process that interacts with enduring vulnerabilities within the marital relationship to shape caregivers' evaluations of the marriage; our hypotheses based on the VSA model stated that caregivers who report greater perceived partner responsiveness should exhibit weaker associations between depressive symptoms or LPS-stimulated proinflammatory cytokine production and marital distress compared to those reporting lower perceived partner responsiveness.

Our findings aligned with the *marital discord model of depression*, which describes the link between difficulties in marital relationships and depressive symptoms through hostile and unsupportive behaviors [31]. Consistent with the model, we found that, among our sample, greater marital distress was associated with more depressive symptoms. Further, our findings contribute to the literature by extending the marital discord model of depression in two important ways. In this study, we found that the positive association between marital distress

and depressive symptoms was stronger among caregivers reporting lower levels of perceived partner responsiveness compared to those reporting higher levels of perceived partner responsiveness. In other words, we found that spousal caregivers who feel less cared for, understood, and appreciated by care partners may be particularly susceptible to the negative consequences associated with marital distress to well-being compared to caregivers who experience greater perceived partner responsiveness from spouses. By focusing on inflammation as an outcome, we also extend the model to consider the potential adverse physiological consequences of marital difficulties. Future work may elaborate on these findings by focusing on how interpersonal characteristics of the marital relationship impact the well-being of both spouses in the context of the ADRD caregiving relationship, such as by examining actor-partner effects or directly observing partner interactions, as has been done in prior work examining marital relationships [51]. However, this research should also account for changes in the marital relationship over time, such as how dementia progression may lead to shifts in marital roles or impact the quality of partner interactions.

Our findings also aligned with the *VSA model*. Although we did not find evidence that depressive symptoms interacted with perceived partner responsiveness to shape caregivers' evaluations of the marital relationship, we found that levels of proinflammatory cytokine production interacted with perceived partner responsiveness to shape marital distress among our sample of caregivers. Specifically, among caregivers, elevated levels of proinflammatory cytokine production were associated with greater marital distress, and this association was weaker among caregivers who reported higher levels of perceived partner responsiveness. These findings are consistent with prior research considering perceived partner responsiveness as an important adaptive process within the marriage that may attenuate the effects of enduring vulnerabilities and stressors on evaluations of the marital relationship [24]. However, we also extend the VSA model to consider how heightened inflammation may shape evaluations of the marital relationship in the context of caregiving for a spouse with ADRD. As inflammation may increase neural sensitivity to both negative and positive social stimuli [52], the effects of heightened inflammation on marital distress may depend on differences in how caregivers perceive care partners' responsiveness. Future studies may further elaborate on these findings by utilizing experimental paradigms that induce heightened inflammation and allow for assessing potential changes in caregivers' evaluations of their partners' responsive behavior as a result.

The strengths of our study include a rigorous methodology utilizing a biopsychosocial approach to understanding the factors influencing well-being among caregivers. In this study, we utilized LPS-stimulated proinflammatory cytokine production as an index of chronic inflammation. Our findings are in line with several studies that have shown similar associations between LPS-stimulated proinflammatory cytokine production and depressive symptoms [53]. As we investigated the potential associations between marital relationship characteristics and psychological (i.e., depressive symptoms) and physiological (i.e., inflammation) health outcomes, we add to the literature seeking to disentangle why some ADRD spousal caregivers are more at risk of poor health compared to other caregivers. Much biopsychosocial work on dementia spousal caregivers has focused on how they differ from matched comparisons. Yet, it is critical to understand the factors that contribute to the subset of dementia spousal caregivers who are most at risk for chronic health problems.

These findings, however, must be considered in light of several limitations. First, we cannot infer causal relationships between the study variables, as we utilized cross-sectional data. Future studies should use longitudinal designs to establish temporal precedence and better characterize the relationships between marital distress, perceived partner responsiveness, and well-being among caregivers. Studies utilizing longitudinal designs may also allow for assessing and comparing changes in levels of proinflammatory cytokine production over time, as has been done in studies assessing age-related increases in proinflammatory cytokine production among caregivers [19]. Further, our study was also limited by



our sample composition, which was predominantly female and of relatively high socioeconomic status. However, women are more likely to take on the role of caregiver for someone living with dementia; about two-thirds of dementia caregivers are women [54]. Another limitation of the study is that our sample predominantly consisted of White participants. Future research should consider how the experience of ADRD spousal caregiving varies across racial, ethnic, and cultural groups, as previous studies have reported differences in caregiver stress and coping [55].

We also recognize that our study may have been insufficiently powered to detect an interaction effect between marital distress and perceived partner responsiveness, which could also have contributed to the unexpected patterns of results. Other studies examining interactions similar to those in this study have demonstrated small to moderate-sized effects [25,56]. Indeed, a post hoc power analysis conducted using the *pwr* package in R (v1.3.0) [44] indicated that we had 18 % power for detecting a small-sized effect ( $f^2 = 0.02$ ) when employing the traditional 0.05 criterion of statistical significance with our study sample. Thus, we additionally conducted our primary analyses within a Bayesian framework, which provides model estimates and related uncertainty as a probability distribution and produces reasonable results even with smaller sample sizes [57]. We accounted for missing data with random forest imputation using the “bagImpute” method of the “preProcess” function within the *caret* package (v6.0-94) [58]. Using the *brms* package in R (v2.21.0) [59], which utilizes the probabilistic programming language Stan [60], we ran Bayesian multiple regression models corresponding to our primary hypotheses to quantify the probability of the alternative hypotheses, given the data. Our findings from the models testing the marital discord model of depression revealed that there was a 98 % and 99 % probability that an interaction between marital distress and perceived partner responsiveness predicted depressive symptoms or the composite inflammatory index, respectively (Supplementary Table 1). Further, our findings from the models testing the VSA model revealed that there was a 98 % probability that an interaction between the composite inflammatory index and perceived partner responsiveness predicted marital distress (Supplementary Table 2). When further probing interactions, we found that the patterns of results were unchanged from those reported in our primary analyses.

Finally, our findings also revealed some unexpected patterns of results. When considering the effect of perceived partner responsiveness on depressive symptoms across levels of marital distress, we found that greater perceived partner responsiveness was associated with more depressive symptoms only among caregivers reporting low levels of marital distress. When considering the effect of perceived partner responsiveness on the composite inflammatory index across levels of marital distress, perceived partner responsiveness was also not associated with the composite inflammatory index among caregivers reporting low, mean, or high levels of marital distress. One possible reason for these findings is that other potential factors not examined here may have also influenced the impact of perceived partner responsiveness on caregivers. For instance, prior studies have shown that evaluations of the marital relationship and perceived partner responsiveness may influence the spouse’s well-being, in turn influencing the spouse’s own responsive behavior [61,62]. Future research should account for these factors by considering how marital distress and perceived partner responsiveness may interact between the caregiver and care partner. Additionally, these findings may also reflect characteristics of our study sample, which is another potential limitation of our cross-sectional study design. Future studies can address this limitation by utilizing longitudinal designs that allow for assessing changes in caregiver marital distress, perceived partner responsiveness, and well-being over time. These studies may also examine non-caregivers as well as caregivers to determine whether these findings are unique to the context of caregiving.

Among ADRD spousal caregivers, we found that perceived partner responsiveness moderated the associations between marital distress and

psychological (i.e., depressive symptoms) as well as physiological (i.e., LPS-stimulated proinflammatory cytokine production) health indicators. Interventions facilitating supportive interpersonal behaviors within the caregiving relationship may promote caregiver well-being. These findings contribute to our growing understanding of the interpersonal characteristics associated with the mental and physical health of dementia spousal caregivers.

#### CRediT authorship contribution statement

**Vincent D. Lai:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Jensine Paoletti-Hatcher:** Writing – review & editing, Software, Conceptualization. **E. Lydia Wu-Chung:** Writing – review & editing, Software, Conceptualization. **Itee Mahant:** Writing – review & editing, Investigation, Data curation. **Daniel L. Argueta:** Writing – review & editing, Investigation. **Kelly N. Brice:** Writing – review & editing, Investigation. **Bryan T. Denny:** Writing – review & editing, Supervision, Investigation. **Charles Green:** Writing – review & editing, Software. **Luis D. Medina:** Writing – review & editing, Supervision. **Paul E. Schulz:** Writing – review & editing, Resources. **Jennifer M. Stinson:** Writing – review & editing, Resources. **Cobi J. Heijnen:** Writing – review & editing, Supervision. **Christopher P. Fagundes:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

#### Declaration of competing interest

The authors have no conflicts of interest to disclose.

#### Acknowledgements

This work was supported by the National Institute on Aging (Fagundes-R01AG062690). Authors are also funded by the following: Fagundes-R21AG061597; Paoletti-F32AG079624; Wu-Chung-1F31AG074648. We are truly grateful to the caregivers who devoted their valuable time to the study. We would also like to thank Kristi English, Ann Wang, Temilade Dada, and our dedicated research assistants for their hard work in recruiting participants and leading experimental visits.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cpnc.2024.100271>.

#### References

- [1] S. Stack, J.R. Eshleman, Marital status and happiness: a 17-nation study, *J. Marriage Fam.* 60 (2) (1998) 527–536, <https://doi.org/10.2307/353867>.
- [2] M.E. Dupre, A.N. Beck, S.O. Meadows, Marital trajectories and mortality among US adults, *Am. J. Epidemiol.* 170 (5) (2009) 546–555, <https://doi.org/10.1093/aje/kwp194>.
- [3] L. Manzoli, P. Villari, G. M. Pirone, A. Boccia, Marital status and mortality in the elderly: a systematic review and meta-analysis, *Soc. Sci. Med.* 64 (1) (2007) 77–94, <https://doi.org/10.1016/j.socscimed.2006.08.031>.
- [4] E.M. Lawrence, R.G. Rogers, A. Zajacova, T. Wadsworth, Marital happiness, marital status, health, and longevity, *J. Happiness Stud.* 20 (5) (2019) 1539–1561, <https://doi.org/10.1007/s10902-018-0009-9>.
- [5] R. Blieszner, P.A. Shifflett, The effects of Alzheimer’s disease on close relationships between patients and caregivers, *Fam. Relat.* 39 (1) (1990) 57–62, <https://doi.org/10.2307/584949>.
- [6] M. O’Shaughnessy, K. Lee, T. Lintern, Changes in the couple relationship in dementia care: spouse carers’ experiences, *Dementia* 9 (2) (2010) 237–258, <https://doi.org/10.1177/1471301209354021>.
- [7] J.L. Funk, R.D. Rogge, Testing the ruler with item response theory: increasing precision of measurement for relationship satisfaction with the Couples Satisfaction Index, *J. Fam. Psychol.* 21 (4) (2007) 572–583, <https://doi.org/10.1037/0893-3200.21.4.572>.

- [8] N.S. Jacobson, A. Christensen, *Integrative Couple Therapy: Promoting Acceptance and Change*, W W Norton & Co, 1996, p. 283, xiv.
- [9] M.A. Whisman, D.H. Baucum, Intimate relationships and psychopathology, *Clin. Child Fam. Psychol. Rev.* 15 (1) (2012) 4–13, <https://doi.org/10.1007/s10567-011-0107-2>.
- [10] D.E. Mead, Marital distress, Co-occurring depression, and marital therapy: a review, *J. Marital Fam. Ther.* 28 (3) (2002) 299–314, <https://doi.org/10.1111/j.1752-0606.2002.tb01188.x>.
- [11] M.A. Whisman, Marital distress and DSM-IV psychiatric disorders in a population-based national survey, *J. Abnorm. Psychol.* 116 (3) (2007) 638–643, <https://doi.org/10.1037/0021-843X.116.3.638>.
- [12] Y.C. Schonbrun, M.A. Whisman, Marital distress and mental health care service utilization, *J. Consult. Clin. Psychol.* 78 (5) (2010) 732–736, <https://doi.org/10.1037/a0019711>.
- [13] E.D. Rankin, M.W. Haut, R.W. Keefe, Current marital functioning as a mediating factor in depression among spouse caregivers in dementia, *Clin. Gerontol.: The Journal of Aging and Mental Health* 23 (3–4) (2001) 27–44, [https://doi.org/10.1300/J018v23n03\\_04](https://doi.org/10.1300/J018v23n03_04).
- [14] C. Williams, Marriage and mental health: when a spouse has Alzheimer's disease, *Arch. Psychiatr. Nurs.* 25 (3) (2011) 220–222, <https://doi.org/10.1016/j.apnu.2011.02.003>.
- [15] M. Braun, K. Mura, M. Peter-Wight, R. Hornung, U. Scholz, Toward a better understanding of psychological well-being in dementia caregivers: the link between marital communication and depression, *Fam. Process* 49 (2) (2010) 185–203, <https://doi.org/10.1111/j.1545-5300.2010.01317.x>.
- [16] J.K. Kiecolt-Glaser, J.P. Gouin, L. Hantsoo, Close relationships, inflammation, and health, *Neurosci. Biobehav. Rev.* 35 (1) (2010) 33–38, <https://doi.org/10.1016/j.neubiorev.2009.09.003>.
- [17] W.B. Ershler, E.T. Keller, Age-associated increased interleukin-6 gene expression, late-life diseases, and frailty, *Annu. Rev. Med.* 51 (1) (2000) 245–270, <https://doi.org/10.1146/annurev.med.51.1.245>.
- [18] C.J. Donoho, E.M. Crimmins, T.E. Seeman, Marital quality, gender, and markers of inflammation in the MIDUS cohort, *J. Marriage Fam.* 75 (1) (2013) 127–141, <https://doi.org/10.1111/j.1741-3737.2012.01023.x>.
- [19] J.K. Kiecolt-Glaser, K.J. Preacher, R.C. MacCallum, C. Atkinson, W.B. Malarkey, R. Glaser, Chronic stress and age-related increases in the proinflammatory cytokine IL-6, *Proc. Natl. Acad. Sci. USA* 100 (15) (2003) 9090–9095, <https://doi.org/10.1073/pnas.1531903100>.
- [20] H.T. Reis, Perceived partner responsiveness as an organizing theme for the study of relationships and well-being, in: *Interdisciplinary Research on Close Relationships: The Case for Integration*, American Psychological Association, 2012, pp. 27–52, <https://doi.org/10.1037/13486-002>.
- [21] T.A. Jolink, Y.P. Chang, S.B. Algoe, Perceived partner responsiveness forecasts behavioral intimacy as measured by affectionate touch, *Pers. Soc. Psychol. Bull.* 48 (2) (2022) 203–221, <https://doi.org/10.1177/0146167221993349>.
- [22] E. Selcuk, S.C.E. Stanton, R.B. Slatcher, A.D. Ong, Perceived partner responsiveness predicts better sleep quality through lower anxiety, *Soc. Psychol. Personal. Sci.* 8 (1) (2017) 83–92, <https://doi.org/10.1177/1948550616662128>.
- [23] E. Selcuk, G. Gunaydin, A.D. Ong, D.M. Almeida, Does partner responsiveness predict hedonic and eudaimonic well-being? A 10-year longitudinal study, *J. Marriage Fam.* 78 (2) (2016) 311–325, <https://doi.org/10.1111/jomf.12272>.
- [24] P.R. Pietromonaco, N.C. Overall, S.I. Powers, Depressive symptoms, external stress, and marital adjustment: the buffering effect of partner's responsive behavior, *Soc. Psychol. Personal. Sci.* 13 (1) (2022) 220–232, <https://doi.org/10.1177/19485506211001687>.
- [25] R.N. Balzarini, A. Muise, G. Zoppolat, et al., Love in the time of COVID: perceived partner responsiveness buffers people from lower relationship quality associated with COVID-related stressors, *Soc. Psychol. Personal. Sci.* 14 (3) (2023) 342–355, <https://doi.org/10.1177/19485506221094437>.
- [26] E.R. Champagne, A. Muise, Responsiveness and relationship satisfaction in couples coping with Parkinson's disease: a pilot study, *Psychol. Rep.* 125 (2) (2022) 804–821, <https://doi.org/10.1177/0033294121998032>.
- [27] G. Ferraris, E. Bei, C. Coumoudourou, et al., The interpersonal process model of intimacy, burden and communal motivation to care in a multinational group of informal caregivers, *J. Soc. Pers. Relat.* (2023) 02654075231174415, <https://doi.org/10.1177/02654075231174415>. Published online May 17.
- [28] K. Hooker, S.R. Bowman, D.P. Coehlo, et al., Behavioral change in persons with dementia: relationships with mental and physical health of caregivers, *J. Gerontol.: Ser. Bibliogr.* 57 (5) (2002) P453–P460, <https://doi.org/10.1093/geronb/57.5.P453>.
- [29] M.C. Norton, K.W. Piercy, P.V. Rabins, et al., Caregiver–recipient closeness and symptom progression in Alzheimer disease. The cache county dementia progression study, *J. Gerontol.: Ser. Bibliogr.* 64B (5) (2009) 560–568, <https://doi.org/10.1093/geronb/gbp052>.
- [30] R.B. Slatcher, E. Selcuk, A.D. Ong, Perceived partner responsiveness predicts diurnal cortisol profiles 10 Years later, *Psychol. Sci.* 26 (7) (2015) 972–982, <https://doi.org/10.1177/0956797615575022>.
- [31] S.R.H. Beach, E. Sandeen, K.D. O'Leary, *Depression in Marriage: A Model for Etiology and Treatment*, Guilford Press, 1990.
- [32] J.K. Kiecolt-Glaser, T.J. Loving, J.R. Stowell, et al., Hostile marital interactions, proinflammatory cytokine production, and wound healing, *Arch. Gen. Psychiatr.* 62 (12) (2005) 1377–1384, <https://doi.org/10.1001/archpsyc.62.12.1377>.
- [33] B.R. Karney, T.N. Bradbury, The longitudinal course of marital quality and stability: a review of theory, methods, and research, *Psychol. Bull.* 118 (1) (1995) 3–34, <https://doi.org/10.1037/0033-2909.118.1.3>.
- [34] C. Peterson, C.W. O'Neal, T.G. Futris, Military couples' childhood experiences and romantic relationship satisfaction: the role of accepting influence, *Fam. Process* 61 (2) (2022) 689–704, <https://doi.org/10.1111/famp.12689>.
- [35] F.D. Fincham, S.R.H. Beach, G.T. Harold, L.N. Osborne, Marital satisfaction and depression: different causal relationships for men and women? *Psychol. Sci.* 8 (5) (1997) 351–356, <https://doi.org/10.1111/j.1467-9280.1997.tb00424.x>.
- [36] N.I. Eisenberger, T.K. Inagaki, N.M. Mashal, M.R. Irwin, Inflammation and social experience: an inflammatory challenge induces feelings of social disconnection in addition to depressed mood, *Brain Behav. Immun.* 24 (4) (2010) 558–563, <https://doi.org/10.1016/j.bbi.2009.12.009>.
- [37] T.L. Schuster, R.C. Kessler, Jr.RH. Aseltine, Supportive interactions, negative interactions, and depressed mood, *Am. J. Community Psychol.* 18 (3) (1990) 423–438, <https://doi.org/10.1007/BF00938116>.
- [38] L.S. Radloff, The CES-D scale: a self-report depression scale for research in the general population, *Appl. Psychol. Meas.* 1 (3) (1977) 385–401, <https://doi.org/10.1177/014662167700100306>.
- [39] M.K. Song, F.C. Lin, S.E. Ward, J.P. Fine, Composite variables: when and how, *Nurs. Res.* 62 (1) (2013) 45, <https://doi.org/10.1097/NNR.0b013e3182741948>.
- [40] C.P. Fagundes, R.L. Brown, M.A. Chen, et al., Grief, depressive symptoms, and inflammation in the spousally bereaved, *Psychoneuroendocrinology* 100 (2019) 190–197, <https://doi.org/10.1016/j.psyneuen.2018.10.006>.
- [41] E.L. Wu, A.S. LeRoy, C.J. Heijnen, C.P. Fagundes, Inflammation and future depressive symptoms among recently bereaved spouses, *Psychoneuroendocrinology* 128 (2021) 105206, <https://doi.org/10.1016/j.psyneuen.2021.105206>.
- [42] M.F. O'Connor, J.E. Bower, H.J. Cho, et al., To assess, to control, to exclude: effects of biobehavioral factors on circulating inflammatory markers, *Brain Behav. Immun.* 23 (7) (2009) 887–897, <https://doi.org/10.1016/j.bbi.2009.04.005>.
- [43] M. Charlson, T.P. Szatrowski, J. Peterson, J. Gold, Validation of a combined comorbidity index, *J. Clin. Epidemiol.* 47 (11) (1994) 1245–1251, [https://doi.org/10.1016/0895-4356\(94\)90129-5](https://doi.org/10.1016/0895-4356(94)90129-5).
- [44] S. Champely, Pwr: basic functions for power analysis. <https://CRAN.R-project.org/package=pwr>, 2020.
- [45] R Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, 2023. <https://www.R-project.org/>.
- [46] C.K. Enders, A primer on maximum likelihood algorithms available for use with missing data, *Struct. Equ. Model.: A Multidiscip. J.* 8 (1) (2001) 128–141, [https://doi.org/10.1207/S15328007SEM0801\\_7](https://doi.org/10.1207/S15328007SEM0801_7).
- [47] T. Shin, M.L. Davison, J.D. Long, Maximum likelihood versus multiple imputation for missing data in small longitudinal samples with nonnormality, *Psychol. Methods* 22 (3) (2017) 426–449, <https://doi.org/10.1037/met0000094>.
- [48] Y. Rosseel, Lavaan: an R package for structural equation modeling, *J. Stat. Software* 48 (2) (2012) 1–36, <https://doi.org/10.18637/jss.v048.i02>.
- [49] T.D. Jorgensen, S. Pornprasertmanit, A.M. Schoemann, Y. Rosseel, semTools: useful tools for structural equation modeling. <https://CRAN.R-project.org/package=semTools>, 2022.
- [50] C.P. Fagundes, L.M. Diamond, K.P. Allen, Adolescent attachment insecurity and parasymphathetic functioning predict future loss adjustment, *Pers. Soc. Psychol. Bull.* 38 (6) (2012) 821–832, <https://doi.org/10.1177/0146167212437429>.
- [51] J.K. Kiecolt-Glaser, S.J. Wilson, M.L. Bailey, et al., Marital distress, depression, and a leaky gut: translocation of bacterial endotoxin as a pathway to inflammation, *Psychoneuroendocrinology* 98 (2018) 52–60, <https://doi.org/10.1016/j.psyneuen.2018.08.007>.
- [52] N.I. Eisenberger, M. Moieni, T.K. Inagaki, K.A. Muscatell, M.R. Irwin, In sickness and in health: the Co-regulation of inflammation and social behavior, *Neuropsychopharmacology* 42 (1) (2017) 242–253, <https://doi.org/10.1038/npp.2016.141>.
- [53] N. Vogelzangs, P. de Jonge, J.H. Smit, S. Bahn, B.W. Penninx, Cytokine production capacity in depression and anxiety, *Transl. Psychiatry* 6 (5) (2016) e825, <https://doi.org/10.1038/tp.2016.92>.
- [54] Alzheimer's Association, 2023 Alzheimer's disease facts and figures, *Alzheimer's Dementia* 19 (4) (2023) 1598–1695, <https://doi.org/10.1002/alz.13016>.
- [55] M.R. Janovic, C. M Connell, Racial, ethnic, and cultural differences in the dementia caregiving experience: recent findings, *Gerontol.* 41 (3) (2001) 334–347, <https://doi.org/10.1093/geront/41.3.334>.
- [56] E. Selcuk, A.D. Ong, Perceived partner responsiveness moderates the association between received emotional support and all-cause mortality, *Health Psychol.* 32 (2) (2013) 231–235, <https://doi.org/10.1037/a0028276>.
- [57] S. Depaoli, H.M. Rus, J.P. Clifton, R. van de Schoot, J. Tiemensma, An introduction to Bayesian statistics in health psychology, *Health Psychol. Rev.* 11 (3) (2017) 248–264, <https://doi.org/10.1080/17437199.2017.1343676>.
- [58] M. Kuhn, Building predictive models in R using the caret package, *J. Stat. Software* 28 (2008) 1–26, <https://doi.org/10.18637/jss.v028.i05>.
- [59] P.C. Bürkner, Brms: an R package for bayesian multilevel models using stan, *J. Stat. Software* 80 (2017) 1–28, <https://doi.org/10.18637/jss.v080.i01>.
- [60] Stan Development Team, Stan modeling language users guide and reference manual, Published online, <https://mc-stan.org>, 2024.
- [61] A.S. O'Neill, C.D. Mohr, T.E. Bodner, L.B. Hammer, Perceived partner responsiveness, pain, and sleep: a dyadic study of military-connected couples, *Health Psychol.* 39 (12) (2020) 1089–1099, <https://doi.org/10.1037/hea0001035>.
- [62] L. Clare, S.M. Nelis, C.J. Whitaker, et al., Marital relationship quality in early-stage dementia: perspectives from people with dementia and their spouses, *Alzheimer Dis. Assoc. Disord.* 26 (2) (2012) 148, <https://doi.org/10.1097/WAD.0b013e318221ba23>.