ASSOCIATIONS BETWEEN DAILY PAIN COMMUNICATION AND PHYSICAL HEALTH FOR
CHRONIC PAIN PATIENTS AND THEIR SPOUSES

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ABSTRACT

The majority of older adults in the U.S. and other countries suffer from persistent pain. As a leading contributor to missed work, lost wages, and medical expenses, the cost of chronic pain and pain-related disability in the United States is estimated at an annual $635 billion. Indeed, when pain is chronic, problems arise for individuals, families, and societies because of its long-term impairment on everyday physical function.

Together, the present studies seek to elucidate the health effects of pain expression and spouse responses for patients and spouses in daily life using intensive longitudinal assessments. Study 1 examines the frequency of patient pain expression in daily life and spousal parasympathetic activity in response to patient pain expression during interactions audio-recorded in the homes of three couples. In order to gauge the long-term physical impact of daily spouse responsiveness on patients, Study 2 investigates the associations of daily pain expression and spouse responses with changes in patient physical function over 18 months.

Study 1 found that the frequency of pain expression varied across the three patients—none, on average 3 times per day, and an average of 11 times daily. Also, contrary to prediction, spouse respiratory sinus arrhythmia (RSA) increased after patient expression, suggesting successful emotion regulation and social engagement. Results from Study 2 suggest daily empathic spouse responsiveness promotes long-term improvement of patient physical function.

Together, the current studies illustrate the proximal and distal health consequences of couples’ daily interaction patterns for patients and spouses.
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Chapter 1

Introduction

The majority of older adults in the U.S. and other countries suffer from persistent pain (Henderson, Harrison, Britt, Bayram, & Miller, 2013; Leadley, Armstrong, Lee, Allen, & Kleijnen, 2012; Molton & Terrill, 2014; Patel, Guralnik, Dansie, & Turk, 2013; Reid, Eccleston, & Pillemer, 2015). As a leading contributor to missed work, lost wages, and medical expenses, the cost of chronic pain and pain-related disability in the United States is estimated at an annual $635 billion (Institute of Medicine, 2011). Indeed, when pain is chronic, problems arise for individuals, families, and societies because of its long-term impairment on everyday physical function. Understanding how pain interactions impact pain sufferers and their loved ones may inform interventions that benefit the well-being of individuals and families and, in turn, societies' health and productivity. Together, the present studies seek to elucidate the health consequences of pain expression and spouse responses for patients and spouses in daily life using intensive longitudinal assessments. Study 1 examines spousal parasympathetic activity in response to patient pain expression during couples’ daily interactions in the home as a proximal mechanism of spouses’ heightened risk for cardiovascular disease. In order to gauge the long-term physical impact of daily spouse responsiveness, Study 2 investigates the associations of daily pain expression and spouse responses with changes in patient physical function over 18 months.

Pain as a Communicative Process

Pain is a social experience. Evolutionary incentives encourage those in pain to express it to others, and the presence of a close other can even assuage the aversive neural response to pain (Coan, Schaefer, & Davidson, 2006). Indeed, communicating pain can elicit responses from social partners that may both benefit the pain sufferer and maintain the safety and well-being of the group (Hadjistavropoulos et al., 2011). However, when pain is chronic, the social dynamics of its expression are especially complex. If the sufferer continues with verbal and nonverbal
requests for emotional and physical support, benevolent responses may devolve into more volatile and punishing ones (McCracken, 2005), and social connections themselves may weaken (Bolger, Foster, Vinokur, & Ng, 1996; Crouch, Skowronski, Milner, & Harris, 2008; Kaniasty & Norris, 1993; Moyer & Salovey, 1999; Norris & Kaniasty, 1996; Quittner, Glueckauf, & Jackson, 1990).

As posited by the biopsychosocial model of pain communication (Hadjistavropoulos et al., 2011), an acute, painful stimulus incites a communicative sequence between sufferer and observer underlain by automatic and controlled neural mechanisms. Pain expression can be accomplished nonverbally—by grimacing, bracing, joint-guarding, groaning, limping—or verbally. Nonverbal acts are considered to reflect automatic processes, carried out with little conscious control. Verbal expression, the more intentional component, acts primarily through executive control. Further, the observer may experience heightened arousal and automatic response tendencies and also offer help. Observers can respond solicitously by providing assistance—encouraging patients to rest, and offering analgesics or food and drink (Romano et al., 1991). Empathic or facilitative responses include affection, active listening, encouragement, and perspective taking. In contrast, observers may respond in a punishing or aggressive way, characterized by irritation, ignoring, and hostility. Furthermore, responses feed back on the painful stimulus, serving to further drive the pain or to squelch it. This communicative process is suspected to have important health implications for both interlocutors, though the immediate and long-term aftermath of chronic pain interactions are poorly understood.

The Effects of Pain Expression on Spouses

Though anyone might observe and respond to pain expression, spouses are of greatest interest as marriage is the central relationship for the majority of middle-aged and older adults with chronic pain. A multitude of studies have demonstrated the profound and multidimensional influence of marriage on physical health (e.g. Cacioppo, Bernston, Sheridan, & McClintock, 2000; Kiecolt-Glaser & Newton, 2001; Robles, Slatcher, Trombello, & McGinn, 2014;
Uchino, Cacioppo, & Kiecolt-Glaser, 1996). The role of the spouse can be especially critical when an individual struggles with an ongoing health challenge, and indeed, spousal interactions have been shown to impact chronic pain patients’ functioning (Schmaling & Goldman Sher, 2000). Likewise, spousal caregivers have been found to face heightened risk for cardiovascular disease and other physical and psychological morbidities (Flor, Turk, & Scholz, 1987; Martire, Keefe, Schulz, Stephens, & Mogle, 2013; Schwartz & Slater, 1991; Vitaliano, Zhang, & Scanlan, 2003).

For spouses of chronic pain patients, witnessing or listening to pain-related suffering may exacerbate such health risks. Evidence from neuroimaging studies indicates that seeing another in pain activates one’s own affective pain centers (Jackson, Meltzoff, & Decety, 2005; Morrison, Lloyd, di Pellegrino, & Roberts, 2004; Saarela et al., 2007; Simon, Craig, Miltner, & Rainville, 2006; Singer et al., 2004) if not sensory pain neural circuitry as well (Lamm, Nusbaum, Meltzoff, & Decety, 2007), such that one may feel both the unpleasantness related to pain and the painful sensation itself. Lab studies probing the consequences of patient pain for spouse autonomic reactivity have examined spouses’ changes in skin conductance, heart rate, respiration rate, and blood pressure—indices of sympathetic nervous system activity or combined sympathetic and parasympathetic activity (Block, 1981; Monin et al., 2010).

The investigation of spousal parasympathetic reactivity (as measured by respiratory sinus arrhythmia, RSA) to patient pain is an important next step given its role in regulation and adaptation (Porges, 2007; Thayer & Lane, 2000). In both theories of parasympathetic nervous system (PNS) activity, the control of the PNS over the heart marks the body’s capacity for responding to the environment appropriately (vagal tone) as well as its efficiency in applying regulatory effort in the moment (vagal brake) and, consequently, is critical for social engagement (Porges, 2007) and attentional control (Thayer & Lane, 2000).

Inhalation and exhalation create a patterned acceleration and deceleration of HR called respiratory sinus arrhythmia (RSA). The PNS can change on the order of milliseconds, making
it the only system fast enough to shift with changes in respiration. Because it is the fastest pattern in an HR signal, its associated variability is also termed high-frequency heart rate variability, HF-HRV. When the environment is deemed safe, the vagal brake is applied or augmented, the sinoatrial node is inhibited, heart rate (HR) decreases, and RSA rises. This inhibition of arousal facilitates exploratory behavior and calm social engagement. When a potentially threatening stressor is detected, the vagal brake is withdrawn or suppressed to allow HR increases and ready the body for response, resulting in reduced RSA. If reductions in PNS influence are insufficient to address the threat, the energy-expensive sympathetic nervous system (SNS) response ensues to prepare fight or flight. After the vagal brake is withdrawn, its reengagement is associated with self-soothing or regulatory behaviors and concomitant increases in RSA.

Consistent with theory, the majority of studies have found that people with higher resting RSA also have more satisfying relationships, greater psychological well-being, more frequent use of emotion regulation strategies, and better physical health (T. W. Smith et al., 2011; Thayer, Åhs, Fredrikson, Sollers III, & Wager, 2012). Conversely, lower tonic RSA has related to risk factors for a variety of chronic conditions: increased hypertension and high cholesterol, leading to cardiovascular disease; higher fasting glucose and hemoglobin A1c levels, increasing the likelihood of diabetes; and heightened urinary cortisol and proinflammatory cytokines, contributing to greater allostatic load (Thayer et al., 2012; Thayer & Lane, 2007; Thayer & Sternberg, 2006). In turn, low levels of RSA have also related to greater chronic illness incidence and heightened mortality risk (Camm et al., 2004; Gerritsen et al., 2001; La Rovere, Bigger, Marcus, Mortara, & Schwartz, 1998; Liao, Carnethon, Evans, Cascio, & Heiss, 2002; Thayer & Lane, 2007).

Not only should follow-up work examine the unique effect of spousal parasympathetic activity to build on previous studies of broad autonomic measures, but studies should also extend examination of reactivity processes to daily life. Though experimental designs that
present spouses with photographs or videos of patients completing painful tasks (e.g. Monin et al., 2010) reduce extraneous environmental variability that may shroud the signal of interest, they simultaneously forfeit applicability to the real world. Studies of pain communication processes in daily life are critical for determining how frequently patients express their pain and with what impact on spouse reactivity. For example, couples’ lives may not resemble interactions in the lab if most of the time they skillfully evade conflictual interaction (cf. T. W. Smith et al., 2011), neglect to share affectionate words (cf. T. W. Smith et al., 2011), or shift the division of labor so as to obviate the pain sufferer’s engagement in debilitating tasks (Martire, Stephens, Druley, & Wojno, 2002; S. J. Smith, Keefe, Caldwell, Romano, & Baucom, 2004).

**The Effects of Pain Expression and Spouse Responses on Patients**

According to an operant conditioning framework, spouses in their attentiveness and helpful responses to patient pain expression unwittingly exacerbate pain and disability by maintaining “sick-role homeostasis”—perpetuating pain behaviors and precluding incompatible well behaviors through reinforcement contingencies (Fordyce, 1976; Kremer, Sieber, & Atkinson, 1985; Raichle, Romano, & Jensen, 2011; Romano et al., 1992, 1995). Conversely, punishing responses such as hostile criticism, mocking, and ignoring, serve to extinguish pain behaviors. On the other hand, the social support perspective has largely emphasized the healing influence of supportive gestures via direct and buffering pathways (Cobb, 1976; Cohen & Wills, 1985), though according to recent work support may cease to benefit health when it challenges patient self-efficacy or is otherwise received as problematic (Bolger, Zuckerman, & Kessler, 2000; Martire et al., 2002; Stephens, Druley, & Zautra, 2002). Together, in partial refutation of the operant hypothesis, the two literatures provide tentative empirical evidence for the beneficial effect of empathic responses to patient pain (akin to received emotional support) and negative consequences of punishing and solicitous responses (akin to hostility and received instrumental support, respectively), on patient physical function, the ability to safely move about to carry out daily activities without assistance. However, the
majority of studies that comprise the corpus of evidence have been limited by cross-sectional designs and measurement flaws that conflate pain sensation and physical function with pain expression. In particular, objective measures of physical function, which typically assess gait speed, balance, and the ability to stand from a chair unassisted, are critical to understanding the long-term impact of responses on patient health because of their strong predictive validity of outcomes such as institutionalization, rehospitalization after discharge, and mortality (Guralnik et al., 2000; Volpato et al., 2011).

**Current Studies**

The current studies seek to advance our empirical understanding of the effects of everyday pain communication on the physical health of chronic pain patients and spouses. Both will add to the literature by contributing externally valid results from data collected by direct observation in couples’ homes and experiences reported as couples go about their daily lives. The studies focus on the verbal mode of pain expression and how it relates to spouse responses and subsequent spouse parasympathetic reactivity and patient physical function, since verbal pain expression in daily interactions could be captured by both the audio-recording method used in Study 1 and ecological momentary assessment in Study 2.

Both studies target important chronic pain populations—adults diagnosed with rheumatoid arthritis (RA) or osteoarthritis (OA). Rheumatoid arthritis is an autoimmune disease of the joints that most commonly afflicts women and older adults (Myasoedova, Crowson, Kremers, Therneau, & Gabriel, 2010). Characterized by volatile flares of joint tenderness, swelling, and pain, inflammatory symptoms can disrupt day-to-day functioning and eventually lead to degradation of joints, severe deformity, and functional impairment (Aletaha et al., 2010; Chan, Felson, Yood, & Walker, 1994; Isomäki, 1992; Reilly, Cosh, Maddison, Rasker, & Silman, 1990). OA is a degenerative disease that also affects the joints and is the most common chronic illness among older adults (Corti & Rigon, 2003). Hip and knee OA are among
the most prevalent causes of pain and can profoundly limit functional ability given their effects on mobility (Corti & Rigon, 2003; Guccione et al., 1994).

Study 1 probes the unexplored mechanism of spousal parasympathetic reactivity in response to patient pain expression as a potential explanation for spousal caregivers’ increased risk for cardiovascular disease. Data were drawn from three couples who participated in a larger in-home pilot study of daily life and RA pain. Patient pain expression was coded from audio recordings, and changes in spouse RSA were examined pre- and post-expression. It was expected that pain expression would be followed by decreases in spousal RSA, indicated a lifting of the vagal brake, challenged emotion regulation, and, therefore, heightened arousal.

Study 2 addresses longstanding questions regarding associations between pain expression, spouse responses, and long-term changes in patient physical function. In a prospective design, 144 osteoarthritis patients and their spouses completed 22-day diaries of pain expression and spouse response and three longitudinal measurements of physical function at baseline, 6 months, and 18 months later. Previous research has attempted to answer these questions primarily with cross-sectional data. This study also builds on the literature by employing a statistical coupling term that explicitly incorporates pain expression (cf. Hadjistavropoulos et al., 2011). Specific objectives include assessing the relevance of daily verbal expression coupling with empathic, punishing, and solicitous spouse responses for later patient physical function. It was anticipated that patients in dyads who have more positive verbal expression-empathic response coupling would also show greater physical function across 18 months than patients whose spouses were less empathically responsive. Conversely, patients whose spouses were more solicitously and punishingly responsive were expected to exhibit steeper linear decreases in physical function across 6 and 18 months.
Chapter 2

Verbal Pain Expression and Real-Time Spousal Parasympathetic Reactivity: A Person-Specific Analysis of a Rheumatoid Arthritis Patient and Her Spouse

Spousal caregivers of chronic pain patients may face heightened risk for cardiovascular disease and other physical and psychological morbidities (Flor et al., 1987; Martire et al., 2013; Schwartz & Slater, 1991; Vitaliano et al., 2003). As an index of self-regulation, parasympathetic reactivity is an important but understudied physiological response to pain expression that may serve as a key mechanism to later decline in physical, particularly cardiovascular, health (Thayer et al., 2012; Thayer & Lane, 2007; Thayer & Sternberg, 2006). Using a person-specific approach, the current study examines the associations between verbal pain expression of rheumatoid arthritis patients and subsequent parasympathetic reactivity of their spouses recorded during the couples’ daily lives.

Central and Autonomic Physiological Responses to Observed Pain

Evidence from neuroimaging studies indicates that observing another in pain activates one’s own affective pain centers (Jackson et al., 2005; Morrison et al., 2004; Simon et al., 2006; Singer et al., 2004) if not sensory pain neural circuitry as well (Lamm et al., 2007), such that one may feel both the unpleasantness related to pain and the painful sensation itself. Osaka and colleagues (2004) found that verbal expressions of pain also triggered responses in the affective pain neural network of listeners. Most studies have used live interactions with strangers, images, or recordings as stimuli. Similar results have been found in a sample of couples who observed each other’s pain (Singer et al., 2004).

As a result of this vicarious experience (Hadjistavropoulos et al., 2011), pain observers also consistently demonstrate heightened autonomic reactivity through increased skin conductance, heart rate, respiration rate, and blood pressure. Craig and colleagues (1968; 1969) reported changes from baseline in skin conductance and heart rate in samples of undergraduate student observers across cold pressor and electric shock paradigms, although in
both studies heart rate decelerated, contrary to prediction. Block (1981) presented participants with video images of painful and neutral faces recorded by their spouses, who at the time were hospitalized for chronic pain, and actors. Skin conductance increased more in reaction to painful faces of spouses and actors compared to neutral ones, as did heart rate to a marginally significant degree. Further, the skin conductance of happily married participants increased more in response to painful images of their spouses than that of participants lower in marital satisfaction. In a study of osteoarthritis patients and their spouses, Monin and colleagues (2010) found that spousal caregivers showed increased diastolic and systolic blood pressure as well as elevated heart rate while watching a stranger complete a painful household task compared to a baseline video. Caregivers showed even sharper increases in response to witnessing the spouse with osteoarthritis complete a painful task compared to observing a stranger, controlling for perceived level of experienced pain. Thus, physiological reactions to observed pain are consistent across autonomic measures, are robust to variations in painful stimuli, and are even stronger in response to a loved one’s pain. Nevertheless, these studies have employed measures that index sympathetic or a combination of sympathetic and parasympathetic nervous system activity, to the exclusion of purely parasympathetic assessments, which have unique theoretical value.

**Theories and Measurement of Parasympathetic Function**

Two established theories have articulated the psychosocial importance of parasympathetic function—polyvagal theory (Porges, 2007) and the model of neurovisceral integration (Thayer & Lane, 2000). The central thesis is shared: strong parasympathetic function allows for flexible and adaptive engagement with and disengagement from the environment, proportionate to the context. Due to the rapid action of the parasympathetic nervous system (PNS) on the heart, behaviors can be adjusted quickly, and because the heart is under constant yet variable inhibitory influence of the PNS, those adjustments are resource-conservative. In both theories, the control of the PNS over the heart marks the body’s capacity
for responding to the environment appropriately (vagal tone) as well as its efficiency in applying regulatory effort in the moment (vagal brake) and, consequently, is critical for social engagement (Porges, 2007) and attentional control (Thayer & Lane, 2000).

Inhalation and exhalation create a patterned acceleration and deceleration of HR called respiratory sinus arrhythmia (RSA). The PNS can change on the order of milliseconds, making it the only system fast enough to shift with changes in respiration. Because it is the fastest pattern in an HR signal, its associated variability is also termed high-frequency heart rate variability, HF-HRV. When the environment is deemed safe, the vagal brake is applied or augmented, the sinoatrial node is inhibited, heart rate (HR) decreases, and RSA rises. This inhibition of arousal facilitates exploratory behavior and calm social engagement. When a potentially threatening stressor is detected, the vagal brake is withdrawn or suppressed to allow HR increases and ready the body for response, resulting in reduced RSA. If reductions in PNS influence are insufficient to address the threat, the energy-expensive sympathetic nervous system (SNS) response ensues to prepare fight or flight. After the vagal brake is withdrawn, its reengagement is associated with self-soothing or regulatory behaviors and concomitant increases in RSA.

Though most studies have examined RSA at rest (tonic) to the exclusion of RSA reactivity (phasic), a few have explored how the two RSA modes may interplay (Butler, Wilhelm, & Gross, 2006; Park, Vasey, Van Bavel, & Thayer, 2014; Segerstrom & Nes, 2007; Uijtdehaage & Thayer, 2000). Park and colleagues (2014) subjected participants to selective attention tasks that varied in neutral and frightening background imagery and perceptual load. Participants low in tonic RSA demonstrated phasic suppression under both low and high levels of perceptual load. On the other hand, those with high tonic RSA were able to augment RSA reactivity in the low-load condition and did not suppress under high perceptual load. Results support the notion that a greater capacity for regulated responding as indexed by tonic RSA translates to the ability to apply the vagal brake in the moment. Though the longitudinal impact
of phasic RSA on tonic levels of RSA has not been studied, a hypothesis for this direction of influence may parallel models in the stress literature that attempt to explain how momentary stressful encounters give way to the development of a chronic stress response and increased allostatic load (McEwen, 1998). Potential processes include repeated hits (i.e. recurrent changes in phasic RSA) and prolonged responses (i.e. failure to return to baseline after a change in phasic RSA, cf. McEwen, 1998; McEwen & Seeman, 1999).

**The Role of RSA in Relationships, Regulation, and Health**

Regardless of the exact dynamics of vagal tone and vagal changes, RSA seems to play a pivotal role in social engagement, emotion regulation, and particularly physical health. The majority of studies have examined between-person differences in tonic RSA and have consistently found that people with higher resting RSA levels also have more satisfying relationships, greater psychological well-being, more frequent use of emotion regulation strategies, and better physical health (T. W. Smith et al., 2011; Thayer et al., 2012). Conversely, lower tonic RSA has related to risk factors for a variety of chronic conditions: increased hypertension and high cholesterol, leading to cardiovascular disease; higher fasting glucose and hemoglobin A1c levels, increasing the likelihood of diabetes; and heightened urinary cortisol and proinflammatory cytokines, contributing to greater allostatic load (Thayer et al., 2012; Thayer & Lane, 2007; Thayer & Sternberg, 2006). In turn, low levels of RSA have also related to greater chronic illness incidence and heightened mortality risk (Camm et al., 2004; Gerritsen et al., 2001; La Rovere et al., 1998; Liao et al., 2002; Thayer & Lane, 2007).

Studies of phasic RSA and its correlates are less abundant but are largely congruent with the tonic RSA literature. For instance, Smith and colleagues (2011) reported that wives showed suppression in RSA after couples took turns discussing one another’s negative attributes. Conversely, wives’ RSA was significantly augmented following couples’ discussions of their positive attributes. In an ambulatory study of individuals with depressive symptoms, Schwerdtfeger and Friedrich-Mai (2009) found that on occasions when symptoms were
elevated, RSA was higher while interacting with family or friends compared to their levels while alone. Augmentations in RSA have been associated with more frequent use of emotion regulation strategies such as reappraisal and suppression (Butler et al., 2006), better ratings of emotion regulation (Hastings et al., 2008), and more positive social functioning (Egizio et al., 2008).

Though associations between pain expression and spouse RSA have not been examined, established theoretical propositions can be extrapolated to couples in the chronic pain context. Consistent with other empirical work that indicates physiological arousal and emotional distress in response to observing pain, patient pain expression may be followed by spousal RSA suppression.

**Continuous Ambulatory Assessment of Pain Expression and Spousal RSA in Chronic Pain**

Many studies in the couples’ communication and chronic pain literatures have been conducted in lab settings where couples are instructed to discuss certain negative and positive topics in a prescribed way for fixed amounts of time or to engage in other structured, pain-inducing activities (Martire et al., 2006; Monin et al., 2010; Romano et al., 1992, 1995; Romano, Jensen, Turner, Good, & Hops, 2000; S. J. Smith et al., 2004; T. W. Smith et al., 2011). While such designs effectively reduce extraneous environmental variability that may shroud the signal of interest, they simultaneously forfeit applicability to the real world. Studies of pain communication processes in daily life are critical for determining how frequently phenomena occur and with what impact. For example, couples’ lives may not resemble interactions in the lab if most of the time they skillfully evade conflictual interaction (cf. T. W. Smith et al., 2011), neglect to share affectionate words (cf. T. W. Smith et al., 2011), or shift the division of labor so as to obviate the pain sufferer’s engagement in debilitating tasks (Martire et al., 2002; S. J. Smith et al., 2004). Even when scenarios in the lab occur in real life, their impact may be tempered by the many distractions of the home environment and the freedom couples have to exit the exchange. Conversely, the impact of daily interactions may be intensified compared to lab-
structured discussions if responses delivered in private fall outside the range of acceptable public behavior.

Cross-sectional, retrospective reports are also widely represented in literatures relevant to chronic pain in couples. Recall errors and biases can shape such reports in profound ways. Details of experiences are summarized and selectively encoded into memory (Bradburn, Rips, & Shevell, 1987; Gorin & Stone, 2001; Stone & Shiffman, 2002), and one’s current psychological state colors retrieval and reconstruction of past experiences (Erskine, Morley, & Pearce, 1990; Salovey, Smith, Turk, Jobe, & Willis, 1993; Schwarz, 1999). In particular, current pain levels affect recall of past painful experiences (Baliki, Geha, & Apkarian, 2009; Erskine et al., 1990; Linton, 1991; Salovey et al., 1993; Stone, Broderick, Porter, & Kaell, 1997; Tennen & Affleck, 1996). Furthermore, survey items often request that participants summarize their experiences over the past week or month, for which weighting of discrete events may differ across people and occasions. Perhaps more commonly, questions are not anchored by any time reference, leaving interpretation open to wide variation.

A growing number of studies have applied daily diary and ecological momentary assessment (EMA) approaches to chronic pain samples in an effort to understand associations among pain, pain expression, couple interactions around pain, affect, disability, various illness management styles, and pain-management efficacy (Affleck et al., 1999; Affleck, Urrows, Tennen, & Higgins, 1992; Holtzman & DeLongis, 2007; Keefe et al., 1997; Martire et al., 2013; Peters et al., 2000; Sorbi et al., 2006; Wilson et al., 2013). Momentary assessments provide multiple snapshots of daily processes with great external validity and minimized recall bias in a way that more closely approximates the time course across which everyday pain interactions occur (Affleck, Tennen, Urrows, & Higgins, 1991; Bolger, Davis, & Rafaeli, 2003; Bolger, Stadler, Paprocki, & DeLongis, 2009; Stone & Shiffman, 2002).

However, even the most temporally precise self-report design is not likely to capture pain expression as it transpires in daily life. A verbal expression of pain may last as quickly as
hundreds of milliseconds (Levow, 1998) or as long as several seconds. Pain expressions and the interactions they initiate as couples go about their daily activities are likely to be brief, subtle, and habitual enough to evade self-report methods (cf. Mehl, Robbins, & Deters, 2012; Piasecki, Hufford, Solhan, & Trull, 2007). Audio-recordings of participants in their daily lives can detect these brief interactions. Further, these signals are not compromised by non-compliance, recall biases, and unintentional manipulation of the phenomena of interest by survey items themselves. Even studies that use wearable devices to audio-record such as the electronically activated recorder (EAR) report low levels of obtrusiveness and rapid (i.e. 2-hour) habituation to its presence (Mehl & Holleran, 2007; Robbins, López, Weihs, & Mehl, 2014). Further, audio-recording of daily life can provide base rates of the real-world occurrence of pain expression, an important step in contextualizing associations found in lab settings.

RSA is particularly well-suited to questions about physiological reactivity to real-time interactions since it can also shift within seconds and can easily be collected in daily life, compared to some measures of the sympathetic nervous system and hypothalamic pituitary axis. Continuous audio recording and heart rate monitoring together are not only novel but also critical for understanding the links between pain expression and spouse cardiovascular reactivity because they are most likely to capture temporally precise measurements of both in daily life.

The Value of a Person-Specific Approach

Many studies have drawn conclusions about couples’ pain communication from comparisons of couples with chronic pain to those without the condition (e.g. Romano et al., 1992, 1995). Similarly, most studies of phasic RSA have implemented a single task that results in a single reactivity score for each person that is in turn related to other phenomena of interest, capturing between-person differences rather than fluctuations in reactivity. However, many between-person findings have failed to replicate at the within-person, across-time level.
For instance, Keefe and colleagues (1997) found that coping efficacy reported on one day predicted pain and coping strategy use on the same day, as well as the next day's pain, though corresponding between-person relationships were not significant. In short, in many cases momentary phenomena seem to reflect qualitatively different processes and warrant further study.

In particular, examining the role of parasympathetic reactivity in daily pain communication further necessitates a study design that includes within-person, intensive repeated measures over short periods of time. The person-specific approach (Molenaar, 2004) entails collecting enough repeated measures from each person or couple to build a model for their data alone. Generalization to the population can emerge from replication of this process for multiple people and aggregation of person-specific models based on model similarities. Hence, the current study implements a person-specific approach to draw temporally precise conclusions about the within-person processes of pain expression and spouse parasympathetic reactivity in daily life.

**The Current Study**

The present study examined coded audio recordings of verbal pain expression as well as ambulatory measurements of spouse RSA and HR from three couples who participated in a larger in-home pilot study of daily life and rheumatoid arthritis (RA) pain. Rheumatoid arthritis is an autoimmune disease of the joints that most commonly afflicts women and older adults (Myasoedova et al., 2010). Characterized by volatile flares of joint tenderness, swelling, and pain, inflammatory symptoms can disrupt day-to-day functioning and eventually lead to degradation of joints, severe deformity, and functional impairment (Aletaha et al., 2010; Chan et al., 1994; Isomäki, 1992). As leading contributors to disability and missed work, chronically painful conditions such as RA are of growing public health concern (Institute of Medicine, 2011).
The first objective of the current study was to characterize the everyday conversations of couples facing the challenges of RA. How frequently do patients talk about RA, relative to other topics? How often do they verbally express their RA physical symptoms? The second objective was to test associations between symptom expression and parasympathetic reactivity, indexed by RSA. It was expected that decreases in spouse RSA, suppression, would follow patient symptom expression. Secondarily, to replicate previous findings of autonomic changes (Block, 1981; Monin et al., 2010) in a naturalistic setting, spouse HR was predicted to increase after symptom expression, consistent with the expected decreases in RSA.

Method

Participants

Couples were sought through the research registry of a previous study of rheumatoid arthritis, a local rheumatology clinic, the Pennsylvania State University’s research volunteer webpage, and newspaper advertisements. To be eligible, patients were required to have a current rheumatoid arthritis diagnosis, to report at least moderate average daily pain, to have a partner, to live with his or her partner, and to spend at least 8 hours per day with the partner. Patients and partners were not admitted into the study if they had a pacemaker or others living in their residence. Couples in which non-patient partners reported more than mild average daily pain were excluded.

Attempts were made to recruit 6 to 8 couples from a pool of 19 individuals with a diagnosis of rheumatoid arthritis. Eligibility was not assessed for 2 of the 19 individuals, one of whom was not able to be contacted and the other who declined immediately due to illness in the partner. Of the 17 who were screened, 11 were not eligible. Of the 11, 4 reported only mild usual pain; 5 lived with individuals in addition to the partners; and 2 had partners who were deceased or otherwise could not complete study activities. Of the 6 remaining eligible couples, 3 declined because their partners were not interested in the study or were concerned about study demands.
The three couples who met criteria and agreed to complete the study were recruited from the university research volunteer webpage, referral from another participant, and a local rheumatology clinic. All patients were female. Couple 1 was between 55 and 65 years old and had been married for 31 years. Patient 1, whose disease was mild according to a joint count (30 on a scale of 0 – 132), had been diagnosed with RA 5 years prior to the study. Couple 2 was in their 30s and had been married for 12 years. Patient 2 was diagnosed 15 years prior to the study and had extensive joint involvement (severity score = 70 out of 132). Couple 3 was in their 40s and had been together 18 years. Patient 3 also had severe disease (71 out of 132) that had been diagnosed one year prior to the study.

**Measures**

**RA symptom expression.** Patient RA symptom expression was coded in a two-step process. In the first step, coders reliably judged \( k = 0.89 \) the presence or absence of physical symptom expression. Common physical symptoms and complaints included but were not limited to fatigue, cough, congestion, runny nose, muscle soreness, nausea, dizziness, headache, pain, and swelling. Second, the data were coded reliably \( k = 0.94 \) for the presence or absence of rheumatoid arthritis (RA) topics, which included expressions of symptoms like pain, joint swelling, and stiffness, as well as medication and rheumatology care. Fatigue was not included in the RA category, as its etiology is not specific to RA but was frequent enough to have been overrepresented among RA symptoms. Transcribed moans, grunts, and groans were considered RA symptoms only if the surrounding lines were also coded as such. The patients’ conversational turns coded as present for Physical Symptoms and RA-related categories indexed patient verbal expressions of pain and related RA symptoms. Typical examples include “I’m sore;” “I’m swollen;” “That big toe has been bothering me all day;” and “I need my codeine to kick in ‘cause I can’t just lay there and hurt.”

**Interbeat interval (IBI) and accelerometry.** The Actiheart (CamNtech, Cambridge, UK) is a small, lightweight (10 g) two-electrode heart rate monitor and uniaxial accelerometer
designed for extended and unobtrusive wear. The setting with the highest temporal resolution allowed recording of continuous interbeat intervals (IBIs) from a digitized electrocardiogram (ECG) signal using a real-time QRS-detection routine with a sensitivity of 250 µV and resolution of 1 ms. Pregelled Ultratrace ECG Ag/AgCl electrodes (ConMed Corporation, Utica NY) held the device in place. The uniaxial accelerometer detected vertical movement and stored 15-s activity counts at a sampling rate of 32 Hz.

**Procedure**

**Data collection.** Three sets of study activities took place in couples’ homes over the course of 14 days: structured and open-ended interviews; ecological momentary assessment (EMA) of physical symptoms, affect, and arthritis-related interactions with the spouse four times daily; and two 48-hour periods of passive ambulatory recordings of heart rate using Actiheart devices and conversations using stationary microphones.

On Day 1, patient and spouse were asked to provide written informed consent for study participation and then completed the in-person structured interview with a member of the research team, separately from their spouse and in private. Patient and spouse were then trained together in the use of the Verizon smartphone with a manual developed by the study team. Next, both partners’ skin was prepared for application of the heart rate monitor by shaving excess hair if necessary, cleaning the sites with standard disposable isopropyl alcohol pads, and drying and abrading the areas with new, clean washcloths. The study team instructed and assisted participants with electrode placement for a preliminary signal test. For women, electrodes were placed laterally between V1 and V2 and for men, between V4 and V5, starting with the sternum then extending above or below the left breast, respectively, until the lead was taut, minimizing signal disruptions. After a brief period of emulating movements from daily activities while wearing the device, the quality of the signal-to-noise ratio was assessed, and electrodes were shifted if necessary. Finally, the stationary microphones were placed in two non-private rooms of the participants’ choice. Couples received a binder of study information,
additional electrode pads, a placard notifying visitors of the audio recorders, and a packet of questionnaires to complete privately prior to the second home visit.

On Day 3, a standard baseline task and open-ended interview about experiences with rheumatoid arthritis were completed by patient and spouse separately during heart rate assessment. Self-administered questionnaires, stationary microphones, and heart rate monitors were collected from participants at the conclusion of the visit. On Day 12, a study team member assisted participants in reapplying heart rate monitors and setting up stationary microphones for the second 48-hour period. After Day 14, all study materials were collected from the home, and patient and spouse were each given $200 for their participation.

**Audio coding.** Audio recordings were contained in mp3 files produced by Olympus DM-620 recorders (Olympus, Center Valley, PA). These recordings were transcribed verbatim and deidentified by members of the study team. Transcriptions were segmented into conversational turns and independent clauses. Categories of interest such as pain expression and spouse responses were identified a priori and refined for the context through an iterative process of group discussion and consideration of the data, consistent with an interim analytic approach (Miles & Huberman, 1984). Undergraduate research assistants were trained by two members of the study team to code couples’ recorded speech through rounds of practice coding and discussion. Independent coders achieved reliability of at least $k = .80$ or $r = .80$ for all categories and periodically completed refresher rounds of reliability training and testing.

**Audio-physiology alignment.** Stationary audio recorders and heart rate monitors were synced to the current time of day but operated independently of each other. This temporal independence could introduce random error or bias. First, any two signals could be misaligned by a constant, perhaps starting with two slightly different times. Second, recordings could accelerate or decelerate at different rates (Elson & Estrin, 2001). Third, there could be intermittent decreases in precision associated with missed heartbeats.
To confirm proper temporal alignment of sensors, *crossover events*, or audible moments that are physiologically meaningful, were identified in the data to serve a function similar to that of a clapboard in filmmaking. For instance, standing up from a chair can be an audible occurrence that produces a surge in heart rate, countering the downward force of gravity to maintain oxygen levels in the brain and upper body (Grubb & Karabin, 2008). Any startle response should be marked by a rise in heart rate and possibly a yell or other automatic verbal expression. Such instances were identified, and their accompanying times were recorded. Time stamps were converted from characters to POSIXct to seconds and formatted into vectors. Next, times of the events on the audio files were used to predict the times of patient physiological measures (i.e. heart rate and physical activity estimates for equal 15-s intervals) in a linear regression. Regression results provided information about shifts, acceleration or deceleration, and potentially event-related misalignment. Fitted-value and residual plots were examined. This procedure was carried out for the three spouses’ physiological data, except the second weekend of Spouse 1, which only had one identifiable crossover event. None required realignment.

**IBI Cleaning and HR, RSA Calculation**

IBIs were read from Actiheart devices into the Actiheart software, where they were cleaned in a first pass using the program’s automated routine (CamNtech, 2013). In a second pass, IBIs were visually inspected and cleaned in CardioEdit by a study team member who achieved reliability in the Porges method of IBI cleaning as well as a supervised research assistant (Brain-Body Center, 2007). Missing beats were then interpolated to preserve the length of the time series (Peltola, 2012). Heart rate values were calculated in beats per minute (BPM) by dividing 60,000 by each IBI.

Though there is no single standard for quantifying RSA, two general approaches are widely used, time-domain and frequency-domain analysis (Lewis, Furman, McCool, & Porges, 2012; Task Force of the European Society of Cardiology and the North American Society of
Pacing and Electrophysiology, 1996). Time-domain techniques reflect the degree of variation in interbeat intervals over a defined period. Frequency-domain methods apply spectral analysis to extract the high-frequency heart rate variability (HF-HRV) signal that varies with respiration.

Models were fit using one method from each approach. The time-domain technique root mean square of successive differences (RMSSD) was applied to capture the square root of the average of squared differences in interbeat intervals. The R function rmssd in the package {psych} used Von Neumann's (1941) definition of RMSSD (Revelle, 2015). A frequency-domain method estimated HF-HRV using the program RSAseconds (Gates, Gatzke-Kopp, Sandsten, & Blandon, 2015). The IBI series were interpolated at 250 ms with cubic spline to create equal intervals. The data were then divided using Peak Matched Multiple Windows (Hansson & Jönsson, 2006). With a filter of .12 - .40 Hz (Cacioppo, Tassinary, & Berntson, 2007), a short-time Fourier transform (STFT) was conducted to produce 1-s estimates of HF-HRV from 32-s windows.

**Data Processing**

Windows of 1, 2, and 5 minutes were selected for comparisons of spouse RSA and HR immediately before and after symptom expression. Task Force (1996) recommendations suggest the use of 5-minute estimation windows for short-term recording, though 2- to 5-minute intervals have been widely used. Recent work has sought to capture the dynamic nature of phenomena of interest by reducing the necessary window size without sacrificing the reliability of estimates (Gates et al., 2015). Thus, 1- and 2-minute windows were chosen to match the rapid pace of conversation and changes in RSA. The 5-minute window was also applied to adhere to task force recommendations.

To ensure clear comparisons, any lines of RA symptom expression that contained other lines of RA symptom expression in the 1, 2, or 5 minutes prior to the expression were excluded from 1-, 2-, and 5-minute analyses, respectively. For the 1-minute models, IBIs were extracted 1 minute before and 1 minute after each symptom expression. Series with unusable data were
eliminated. Mean HR, RMSSD, and averaged HF-HRV estimates were calculated for the remaining series. Mean activity count was also computed for pre- and post-expression periods. This sequence was repeated for 2- and 5-minute models.

**Analytic Plan**

Paired samples t-tests were performed to compare RSA (RMSSD and HF-HRV) and HR before and after symptom expression using the three time windows. Because RSA and HR vary systematically with movement, pre-post difference scores in RSA and HR were regressed on pre-post change in mean physical activity. Further, since RSA—specifically RMSSD—may be biased by basal heart rate (Berntson, Lozano, & Chen, 2005), pre-expression heart rate was also included as a covariate in RSA change score models.

**Results**

**Frequency of RA Talk and RA Physical Symptom Expression**

As shown in Table 1, in the 109 minutes Couple 1 talked during the 2 48-hour recording periods, Patient 1 made 705 utterances, none of which regarded RA. Couple 2 conversed for 259 minutes. During that time Patient 2 made 2326 utterances, 26 (1.1%) of which related to RA. The patient expressed RA symptoms in 12 (0.3%) of those utterances.

In 257 minutes of conversation shared by Couple 3, Patient 3 made 1772 utterances, 57 (3.2%) of which were RA-related. Patient 3 expressed her RA symptoms on 43 (2.4%) of those occasions.

**Symptom Expression, RSA, and HR**

Because Patient 1 did not express RA symptoms during the recording period, Couple 1 was excluded from cardiovascular analyses. Couple 2 was also excluded because only 4 of the 12 expressions were analyzable due to missing IBI data and removal of consecutive expressions. Therefore, Couple 3 was the focus for these models; 20 of the 43 expressions were analyzable.
As shown in Table 2, all pre-post changes in spouse RSA across the three time windows and both measures (RMSSD and HF-HRV) fell in the direction opposite prediction. According to RMSSD models, there was a significant increase, or augmentation, 1 and 2 minutes after symptom expression compared to pre-expression levels ($t_{1\text{-min}}(19) = -2.52, p = .021$; $t_{2\text{-min}}(19) = -3.35, p = .003$; see Figure 1). For HF-HRV, significant augmentation was evident only 2 minutes before and after expression ($t(19) = -2.83, p = .011$). These effects remained significant with activity and pre-expression heart rate included, neither of which were statistically significant covariates ($ps > .05$). None of the comparisons were significant in 5-minute windows ($ps > .05$).

Pre-post changes in HR were positive, consistent with hypothesized increases in autonomic arousal, but were not significant at 1-, 2-, or 5-minute windows ($ps > .05$).

**Discussion**

Using ambient audio recordings in couples’ homes and ambulatory IBI assessment, the current study sought to examine spouse parasympathetic reactivity to RA patient symptom expression. Patients varied in their frequency of RA-related physical symptom expression—none, on average 3 times per day, and an average of 11 times daily. The difference between spouse RSA levels pre- and post-expression could not be tested for two couples, and contrary to prediction, the spouse examined in analysis significantly augmented RSA after patient symptom expression, suggesting successful emotion regulation and increased social engagement according to polyvagal theory and the model of neurovisceral integration (Porges, 2007; Thayer & Lane, 2000). Potential explanations and implications for future work are discussed.

**RA Symptom Expression in Daily Life**

In a 4-day period, couples spent between 1.3 and 4.3 hours in conversation. Patients expressed their RA symptoms in 0 - 2.4% of their utterances. Based on the three couples examined in this study, couples for whom RA is likely to emerge as a topic of conversation are, first, generally talkative. Those who discussed RA conversed more than three times longer than the patient who did not broach the topic of RA. Also, according to their narrative interview
responses, the couples who discussed RA in daily life conceived of the illness as shared. That is, both partners in the two couples expressed a preference for the spouse to be involved in illness management, whereas the third couple who did not talk about RA did not conceptualize the illness as the couple’s joint problem (cf. Berg & Upchurch, 2007). Further, the two patients who expressed their RA symptoms had more extensive and severe joint involvement than Patient 1, whose disease was well-managed. Couples in which patients have been newly diagnosed also are likely to talk explicitly about the disease more often, as routines that obviate symptom expression have not yet been established.

Base rates for general RA talk and symptom expression are comparable to frequencies found in a study of cancer patients’ and spouses’ audio-recorded speech (Robbins et al., 2014). Robbins and colleagues reported that 52 couples talked about cancer 4.35% of the time, 2.75% in conversation with each other, from 50-second audio samplings of 9-minute intervals during a 48-hour period. A substantial minority of patients (17%) and spouses (30%) did not talk about cancer during the recording period.

Given the diversity of activities couples engage in as they go about their daily lives, it is unsurprising that a small percentage of all conversations consist of topic-relevant talk. Thus, this study can be considered a successful and informative effort to quantify the frequency of unprompted disease-specific symptom expression using in-home, naturalistic methods. Furthermore, these findings provide insights into the characteristics of couples that the method may capture. Namely, symptom expression is most likely to be detected during the initial or most severe stages of a disease, which are likely to be most physiologically relevant for spouses as well. Patients in couples who typically disclose their thoughts and feelings to each other seem more likely to verbally express their symptoms as well. Studies that seek to elucidate the rapid, micro-level associations between daily expression and immediate physiological responses should consider focusing continuous-recording efforts on couples with these characteristics, as expression must occur for the couple to be analyzed. Alternatively, larger-
scale between-person studies might apply the method by aggregating expressions and RSA during the recording period and examining the association between frequency of expression and RSA.

**Symptom Expression and Spouse RSA**

RSA suppression was predicted to follow patient expression because this lifting of the vagal brake would be consistent with challenged emotion regulation and increases in arousal, as seen in previous studies. Indeed, witnessing pain and suffering has been linked to heightened activity in neural pain centers of the brain (Lamm et al., 2007) and increases in spouse blood pressure and heart rate (Monin et al., 2010). In turn, these patterns have been posited to at least partially explain the heightened risk of cardiovascular disease that spousal caregivers face. However, in the current study spousal parasympathetic augmentation followed patient symptom expression. Several alternative explanations may account for this unexpected result.

First, the theory that any indication of patient pain and suffering inherently distresses spouses may be incorrect. Instead, verbal expression, the focus of the current study, may buffer spouses from heightened arousal by providing greater precision in the location and quality of the symptoms and by giving spouses clearer, more directive information (Hadjistavropoulos et al., 2011). For instance, Wilson, Martire, and colleagues (2013) found that on days when patients verbally express their pain more than usual, spouses respond to nonverbal pain expression with greater empathy and instrumental help, as well as less punishment. Verbal expression has not been examined in previous studies of spouse autonomic responses to patient pain (Block, 1981; Monin et al., 2010).

Additionally, as the incidence of comorbidities rises in the general population, increasingly both partners in a couple are faced with one or more health challenges. In this scenario, symptom expression may be taken as an invitation to share woes or a reminder that the spouse is not alone in his own suffering. Congruence or reciprocity of disclosure in couples
has been found to promote well-being. For example, Hagedoorn and colleagues (2011) reported that patients and spouses who disclosed similar amounts in a discussion task decreased more in their depressive symptoms over four months than those who were incongruent in their disclosure level. Both partners’ diagnoses of health problems may also encourage reciprocity of support, which relates to better well-being in both partners (Acitelli & Antonucci, 1994; Stephens & Clark, 1997). Future work should examine whether spouse disclosure in response to patient symptom expression is linked to spouses’ RSA augmentation as well as better health and well-being.

Characteristics of the spouse or the time period may serve as protective factors as well. As mentioned previously, for spouses with health problems, like Spouse 3 who was experiencing intrusive physical symptoms at the time of the study, patient symptom expression may present an opportunity to bond around common struggles and provide mutual support. The spouse’s illness-specific attributes are also likely to shape the way symptoms are received. For example, Spouse 3’s confidence in communicating with his wife about her pain as well as his low level of critical attitudes may have facilitated vagal augmentation in response to her symptom expression. Also, tonic RSA, an index of regulatory capacity, may prevent spouses from maladaptive momentary reactivity. In a study of tonic and phasic RSA, good regulators—those with high tonic RSA—did not suppress under low or high perceptual load conditions, whereas poor regulators suppressed throughout both tasks (Park et al., 2014). Last, time-varying factors are also likely at play. RA flare-ups come and go, and spouses’ regulatory resources fluctuate. Indeed, Spouse 3 successfully regulated and engaged on more occasions than not, but parasympathetic reactivity varied along a distribution, just as momentary circumstances vary.

Temporal Course of Effects

Very little is known about the temporal course of social processes in general; windows and lags have largely been determined by methodological limitations or model comparisons,
both of which vary across studies (Braga, Zanobetti, & Schwartz, 2001; Dancey, Taghavi, & Fox, 1998; Zanobetti, Wand, Schwartz, & Ryan, 2000). Further, rationales for temporal choices are rarely provided (Braga et al., 2001; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). In the current study, changes in RMSSD were evident within 1 minute. It is expected that the onset of a response would initiate within seconds after symptom expression is processed at the neural level by the spouse since RSA can shift that quickly. However, as a measure of variance, RSA must be estimated with enough data points to reliably capture fluctuations. HF-HRV reactivity was not statistically significant in the 1-minute window perhaps because the algorithm excluded estimates for the first and last 16 seconds of each series and weighted first and last IBIs less heavily (Gates et al., 2015), whereas RMSSD used information from all IBIs equally. The magnitude of the effect was greatest at 2 minutes for both measures of RSA. Perhaps at this interval enough data points offered greater reliability for the signal of interest. Though reactivity and recovery could conceivably occur more quickly, there is no prescribed duration for a conversational topic or regulatory strategy, and in this way reactivity could be behaviorally sustained. It seems that the process of reactivity had fully resolved within 5 minutes, at which point it may be more likely to correspond to a different conversational topic or event. This finding calls into question the utility of the 5-minute standard for dynamic phenomena.

Limitations

The study's limitations are important to acknowledge. First, audio-recording couples in the home naturally excludes couples who do not spend much time at home or converse much. Next, symptoms were expressed in ways not fully captured by the structured coding scheme. Couples, especially those who have had time to jointly adapt to the disease, seemed to accomplish the goal of communicating about and coping with the illness without explicitly expressing and responding to symptoms. For example, according to their narrative interview responses, Couple 1 had developed an understanding that the spouse would take over kitchen
tasks that required dexterity, such as slicing and scooping. Instead of describing her symptoms to justify her requests, Patient 1 would cue her spouse in everyday interaction by announcing her search for a spoon or volunteering the spouse for a task. How this mutual understanding develops and is maintained is an issue that would be well-suited for qualitative analysis.

Further, the signal of spouse reactivity to symptom expression was likely obscured by multiple sources of variability. The method could not guarantee that the spouse, in fact, heard the patient; 2 of the 20 expressions uttered by Patient 3 in particular may have not been heard. Further, 3 of the 20 expressions were in response to spouse inquiries about patient symptoms and, therefore, may not have had as potent an effect since the spouse was already thinking about her symptoms and may have been expecting an expression in response.

**Conclusions**

In an intensive study of couples’ daily lives, patients expressed RA-related symptoms anywhere from 0 to 11 times daily. RA physical symptom expression related to real-time changes in spouse parasympathetic reactivity. RSA augmentation coupled with a lack of significant change in HR points to the importance of measuring both parasympathetic and sympathetic reactivity. Follow-up work with larger samples should also link patterns of momentary reactivity to later assessments of subclinical disease markers such as elevations in blood pressure and arterial calcification and compare the magnitude of effects to those of other daily experiences.
Table 1

Frequencies of Couple Conversation and Patient Symptom Expression

<table>
<thead>
<tr>
<th></th>
<th>Couple 1</th>
<th>Couple 2</th>
<th>Couple 3</th>
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<tbody>
<tr>
<td>Couple talk time (minutes)</td>
<td>109</td>
<td>259</td>
<td>257</td>
</tr>
<tr>
<td>Patient utterance total</td>
<td>705</td>
<td>2326</td>
<td>1772</td>
</tr>
<tr>
<td>Patient RA talk</td>
<td>0 (0%)</td>
<td>26 (1.1%)</td>
<td>57 (3.2%)</td>
</tr>
<tr>
<td>Patient RA symptom expression</td>
<td>0 (0%)</td>
<td>12 (0.5%)</td>
<td>43 (2.4%)</td>
</tr>
</tbody>
</table>

RA symptom expression for spouse RSA analysis

<table>
<thead>
<tr>
<th></th>
<th>Couple 1</th>
<th>Couple 2</th>
<th>Couple 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consecutive expressions removed</td>
<td>0 (0%)</td>
<td>7 (0.3%)</td>
<td>22 (1.2%)</td>
</tr>
<tr>
<td>Expressions with valid spouse RSA data</td>
<td>0 (0%)</td>
<td>4 (0.2%)</td>
<td>20 (1.1%)</td>
</tr>
</tbody>
</table>

Note. All frequencies are expressed in number of utterances, with the exception of couple talk time, reported in minutes. Percentages are of the patient’s total utterances. Indentation indicates nesting. That is, patient RA talk is a subset of the patient’s utterance total, and patient RA symptom expression is a subset of patient RA talk.
Table 2

*Paired Samples T-Tests of Spouse RSA and HR Pre- and Post-Expression of RA Symptoms*

<table>
<thead>
<tr>
<th>Window</th>
<th>RMSSD</th>
<th></th>
<th></th>
<th></th>
<th>HF-HRV</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>HR</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t</td>
<td>df</td>
<td>p</td>
<td>t</td>
<td>df</td>
<td>p</td>
<td>t</td>
<td>df</td>
<td>p</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-minute</td>
<td>-2.52</td>
<td>19</td>
<td>0.0210</td>
<td>-1.52</td>
<td>19</td>
<td>0.1453</td>
<td>-0.71</td>
<td>19</td>
<td>0.4869</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-minute</td>
<td>-3.35</td>
<td>19</td>
<td>0.0034</td>
<td>-2.83</td>
<td>19</td>
<td>0.0107</td>
<td>-1.03</td>
<td>19</td>
<td>0.3142</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-minute</td>
<td>-1.21</td>
<td>18</td>
<td>0.2435</td>
<td>-1.71</td>
<td>18</td>
<td>0.1045</td>
<td>-0.71</td>
<td>18</td>
<td>0.4842</td>
<td></td>
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</table>

*Note.* Couple 3 only. Because post-expression values were subtracted from pre-expression, negative *t* values reflect increases (for RSA, augmentation), and positive *t* values indicate decreases, or RSA suppression. RMSSD = root mean square of successive differences. HF-HRV = high-frequency heart rate variability.
Figure 1. Distribution of Spouse 3 RMSSD reactivity scores 2 minutes before and after RA symptom expression
Chapter 3

The Long-Term Implications of Spouse Responsiveness for Health

The quality of close relationships has been found to influence a range of meaningful physical health outcomes—the rate at which wounds heal (Kiecolt-Glaser et al., 2005), the likelihood of a cardiac event (Orth-Gomér et al., 2000), the length of postoperative recovery time (Kulik & Mahler, 2006), and risk of death (Eaker, Sullivan, Kelly-Hayes, D'Agostino, & Benjamin, 2007). A recent meta-analysis compared relationship quality to regular exercise and consumption of fruits and vegetables, both in the magnitude of benefits for health and in their daily, habitual occurrence (Robles et al., 2014). Indeed, because social interactions are central to everyday life, growing interest lies in how couples’ daily experiences contribute to changes in physical health.

Conceptual models of stress and allostatic load as well as more general developmental metatheories (Magnusson & Cairns, 1996) suggest the effects of daily experiences, hassles and uplifts accumulate over time to meaningfully alter longer-term health trajectories (Almeida, 2005; Kanner, Coyne, Schaefer, & Lazarus, 1981; McEwen, 1998; Miller, Chen, & Zhou, 2007; Schilling & Diehl, 2014). According to the stress literature, interpersonal stressors and uplifts are among the most impactful of these daily experiences for health and well-being (Almeida, Wethington, & Kessler, 2002; Bolger, DeLongis, Kessler, & Schilling, 1989; Maybery & Graham, 2001) and have consistently related to concurrent changes in physiological markers (Joseph, Kamarck, Muldoon, & Manuck, 2014; Rook, August, Choi, Franks, & Stephens, in press). For example, reporting more daily positive marital interactions relates to less thick carotid arterial walls, whereas the opposite holds true for daily negative marital interactions (Joseph et al., 2014).

Despite the strong conceptual rationale for the role of daily interactions and experiences in long-term health outcomes, the empirical evidence is sparse, likely due to the rarity of multitemporal designs necessary to address such questions (Gerstorf, Hoppmann,
Ram, 2014). Ross and colleagues (2011) discovered that female adolescents who reported more negative daily social interactions also experienced greater increases in metabolic risk across two years. A national study of adults in the U.S. found that participants who were more emotionally reactive to daily stressors during an 8-day diary period were also more likely to report a chronic physical health condition ten years later (Piazza, Charles, Sliwinski, Mogle, & Almeida, 2013). No studies have yet linked couples’ daily interactions with long-term prospective changes in physical health in the kind of multitemporal framework that would allow for strong conclusions regarding temporal sequence.

Among the encounters likely most important to couples’ health are their support-related interactions (Ainsworth, 1969; Bowlby, 1969; Feeney & Collins, 2015). Chronic pain has provided an interesting and fruitful context for the study of support transactions. According to more than 30 years of empirical scrutiny, the reaction of a loved one can either exacerbate or assuage chronic pain and concomitant threats to physical function, the ability to safely move about to carry out daily activities without assistance. Whether the association with physical function is positive or negative has varied by the type of spouse response to pain, similar to the finding that received support does not always benefit the recipient (Cutrona, Shaffer, Wesner, & Gardner, 2007; Uchino, 2009).

Akin to received emotional support, empathic responses to partner pain include affection, active listening, encouragement, and perspective taking. Consistent with models of social support (Cobb, 1976; Cohen & Wills, 1985), empathic responses have often related to better physical function (Romano, Jensen, Schmaling, Hops, & Buchwald, 2009; S. J. Smith et al., 2004). Solicitous responses, gestures of instrumental support, have been linked to worse patient functioning (Flor et al., 1987; Forsythe, Romano, Jensen, & Thorn, 2012; Pence, Thorn, Jensen, & Romano, 2008) through the reinforcement of pain behavior and maintenance of “sick-role homeostasis” (Fordyce, 1976), or through threats to self-efficacy (Martire, Stephens, & Schulz, 2011). Punishing responses to partner pain, characterized by irritation, ignoring, and
hostility have also related negatively to physical function (Burns, Johnson, Mahoney, Devine, & Pawl, 1996; Cano, Johansen, & Franz, 2005), consistent with the notion that aggressive or conflictual interactions serve as stressors (Cohen, 2004).

Most studies of spouse response and patient physical function have been limited by cross-sectional designs that conflate pain sensation and physical function with pain expression. Moreover, mixed results have emerged regarding the association between received emotional support and patient disability in longitudinal studies. In one study, arthritis patients’ quality of received emotional support was related to less self-reported functional disability up to one year later (G. K. Brown, Wallston, & Nicassio, 1989). However, Fekete and colleagues (2006) did not find effects for emotional or problematic support on knee pain or functional limitations two months after knee replacement surgery. Thus, strong directional conclusions regarding the link between daily pain communication and patient physical function cannot be drawn from the extant literature on spouse responses and support. Additionally, objective measures of physical function, which typically assess gait speed, balance, and the ability to stand from a chair unassisted, are critical to understanding the long-term impact of responses on patient health because of their strong predictive validity of outcomes such as institutionalization, rehospitalization after discharge, and mortality (Guralnik et al., 2000; Volpato et al., 2011).

Further, as suggested by the assumption that spouse responses occur in the context of patient pain (Romano et al., 1995, 2000; S. J. Smith et al., 2004), the long-term consequences of spouse responses for patient physical function likely depend on whether the spouse’s behavior occurred in response to or in the absence of pain expression. Empathic behaviors that fluctuate commensurately with pain expression may be particularly beneficial for patients, whereas the same actions independent of expression may not be as salient, or worse, may be received as overinvolved or otherwise problematic (Berg, Meegan, & Deviney, 1998; Burleson, Albrecht, & Sarason, 1994; Martire et al., 2002). Further, previous studies indicate that solicitous responses to pain may pose detrimental to patients’ sense of control and competence (Martire et al.,
2002); this pattern may be particularly pronounced when help attempts co-occur consistently with pain expression day in and day out. In contrast to previous work, the present study used a statistical coupling term to index daily spouse responsiveness to patient pain expression. Similar to studies of daily stress or emotional reactivity, individual slopes were estimated to describe the strength and direction of each couples’ expression-response association. To our knowledge, this represents a novel application of the method to daily interactions and has not been used to operationalize other measures of partner responsiveness (e.g. Maisel & Gable, 2009; Manne, Ostroff, et al., 2004; Reis & Shaver, 1988).

With a combined daily diary and longitudinal approach, the current study sought to examine the association between couples’ daily pain communication and changes in an objective measure of patient physical function across 18 months in a prevalent disease and formidable public health problem, osteoarthritis (OA). Knee OA is a common cause of chronic pain and can profoundly limit functional ability through its effects on mobility (Corti & Rigon, 2003; Guccione et al., 1994), which increases risk for further joint degradation and emergence of comorbidities (Owen, Salmon, Koochsari, Turrell, & Giles-Corti, 2014). Patient physical function is assessed by objective physical performance (Guralnik et al., 1994) in lieu of subjective ratings susceptible to self-report biases (Guralnik et al., 1994; Pryce et al., 2012; Sager et al., 1992). As noted previously, the study design situated spouse responses relative to verbal pain expression in their everyday context, capturing daily spouse responsiveness with a statistical coupling approach.

Associations between the coupling of verbal pain expression with spouse responses on one hand, and prospective shifts in physical function on the other, were tested in three latent-variable multilevel growth models. It was expected that patients whose spouses were more empathically responsive to daily verbal expression (i.e. showed stronger positive coupling between expression and response) would have better physical function 18 months later than patients whose spouses were less empathically responsive. Because solicitous responses to
expression may threaten patients’ sense of control and competence (Martire et al., 2002), patients whose spouses were more solicitously responsive were predicted to experience steeper declines in physical function compared to patients whose spouses were less solicitously responsive. Patient physical function was expected to follow the same course as a result of punishing responsiveness (Burns et al., 2013; Cano, Barterian, & Heller, 2008; Walen & Lachman, 2000).

**Method**

**Study Design**

Data presented in this report were from a larger study of patients diagnosed with knee osteoarthritis (OA) and their spouses that combined in-person interviews conducted over an 18-month period (i.e., T1, T2 at a 6 month follow-up, and T3 at an 18 month follow-up) with a 22-day assessment of daily experiences immediately after the T1 interview (Martire et al., 2013). During the daily assessment protocol, patients and spouses used a handheld computer to answer questions regarding health and affect three times per day (i.e., beginning-of-day, afternoon, and end-of-day), and questions regarding marital and pain-related interactions at end-of-day. The current report utilizes data from the T1, T2, and T3 interviews and end-of-day diary assessments.

**Participants**

To be eligible for the study, patients had to be diagnosed with knee OA by a physician, experience usual knee pain of moderate or greater intensity, be at least 50 years of age, and be married or in a long-term relationship (self-defined) in which they shared a residence with their partner. Exclusion criteria were a comorbid diagnosis of fibromyalgia or rheumatoid arthritis, use of a wheelchair, or a plan to have hip or knee surgery within the following six months. Couples were excluded from the study if the spouse reported arthritis pain of moderate or greater intensity, used a wheelchair, or required assistance with personal care activities. Both partners were required to be cognitively functional as indicated by the accuracy
of their answers to questions regarding the current date, weekday, their age, and birthdate. Both partners also had to be free of any major hearing, speech, or language problems that would interfere with the comprehension and completion of data collection conducted in English.

Primary sources of recruitment were research registries for rheumatology patients and older adults interested in research in the Pittsburgh area, flyers distributed to University of Pittsburgh staff and faculty, and word of mouth. A total of 606 couples were screened for eligibility. Of these, 221 couples declined to participate, and the most frequent reasons were lack of interest ($N = 87$) or illness in the family ($N = 55$). A total of 233 couples were not eligible, and the most frequent reasons were lack of OA in the knee ($N = 55$) or knee OA pain that was mild ($N = 47$). The total enrolled sample was comprised of 152 couples (i.e., 304 individuals).

Of the 152 patients, 150 completed the interviewer-administered physical assessment at T1, 139 had data for the assessment at T2, and 120 patients at T3. A total of 145 couples completed the diary assessment component of the study; their demographics are summarized in Table 1. Altogether, 113 patients underwent all three physical function tests and daily diaries. Of the 32 patients who did not complete some part of the relevant study components, 7 did not report on their daily experiences. Of the 32, 20 were only missing their T3 assessment, 6 missed only T2, and 4 lacked both T2 and T3.

**Data Collection Procedure**

Trained staff interviewed patients and spouses separately in each home. Following the interviews, couples were trained to use the handheld computer (i.e., the Palm TX) as well as familiarized with the format and content of the diary questions. The handheld computer and questionnaire were designed for easy use by older adults and people with minimal computer experience; accessible features included large font size and an oversized stylus for registering responses. Each patient and spouse was provided with a handheld computer that was clearly
labeled with his or her name, and the importance of completing diary assessments
independently was emphasized. Surveys were intended to be completed in the morning,
afternoon, and evening. More specifically, participants were instructed to answer questions: 1) within 60 minutes of rising in the morning, 2) between 2:00 and 4:00 P.M., and 3) upon retiring at night. The current study focuses on end-of-day assessments.

Completion and compliance rates were examined for the diary data. Out of a potential 6380 end-of-day observations (290 individuals in 145 couples x 22 days), a total of 5863 were completed (92%). Compliance with the requested timing of the end-of-day assessment was evaluated by comparing the time of the handheld computer entries with participants’ written log of daily bedtimes. End-of-day assessments that were completed more than 120 minutes before bedtime were excluded from analysis. Using this criterion, 5327 of the 5863 completed observations were included in analysis (i.e., 92% of the completed observations, or 83% of the total possible observations). Completion and compliance rates were very similar for patients and spouses.

**Measures**

**Verbal pain expression.** Patient verbal pain expression was assessed by the spouse at the end of each day with the following 3-point scale item developed for this study (1 = not at all, 2 = somewhat, 3 = very much): “Today, to what extent did your spouse describe his/her pain to you?”

**Spouse responses to patient pain.** Spouse responses to patient pain were assessed by patient report at the end of each day with 9 Likert-type items (1 = not at all, 2 = somewhat, 3 = very much). Six of the items were adapted for daily assessment from the West Haven-Yale Multidimensional Pain Inventory, a valid and reliable measure used in the chronic pain literature (Kerns, Turk, & Rudy, 1985). Three of these items were intended to measure solicitous, spouse behaviors such as offering food or drink, taking over tasks, and encouraging rest (e.g. “Today, your spouse took over your jobs or duties to help you avoid pain”). The other
three items were designed to assess punishing behaviors—ignoring, acting frustrated, and seeming irritated. An example includes “Today, your spouse got frustrated with you when you seemed to be in pain.” The three remaining items, intended to measure empathic responses, were adapted from a scale assessing spouse emotional support in response to patient pain (Stephens, Martire, Cremeans-Smith, Druley, & Wojno, 2006). Items refer to showing affection, understanding patient feelings about the pain, and providing attention (e.g. “Today, your spouse tried to just be there for you when you seemed to be in pain, by giving you his/her undivided attention). Based on findings from the factor analyses described below, ignoring, frustrated, and irritated items were summed to produce a punishing scale. Solicitous items—offering food or drink, taking over tasks, and encouraging rest—were summed to create a scale. The empathic scale was constructed by summing items of showing affection, understanding patient feelings about the pain, and providing attention. Each scale ranged from 3 to 9 with higher scores indicating more of the response. Empathic and solicitous responses were highly correlated at the within-person level ($r = .70$), and both were weakly negatively correlated with punishing responses ($r_{\text{emp-pun}} = -.14$, $r_{\text{sol-pun}} = -.06$).

**Multilevel exploratory factor analysis (EFA) of spouse responses.** Because none of the nine items had been examined at the daily level, a two-level EFA was conducted to investigate the factor structure of spouse responses at both between-couple and within-couple levels. Using Mplus version 6.1 (Muthén & Muthén, 2010), factor parameters were specified such that solutions ranged from one factor for each level to three factors for each level. Accordingly, all possible combinations of factor structures were generated with and without an oblique Geomin rotation, as were their respective fit statistics.

A one-factor within-person, one-factor between-person solution did not fit the data well, as RMSEA and CFI indicators did not meet their recommended cutoff values of .06 and .95, respectively (Hu & Bentler, 1999). Further, for both within- and between-couple levels, items intended as punishing responses loaded very weakly onto the factor. The multilevel two-factor
solution represented a statistically significant improvement to the fit of the data in comparison to the one-factor according to a $X^2$ change test ($X^2(16) = 1106.2, p < .001$), as well as a good fit overall (RMSEA = .04; CFI = .96). The within- and between-person solutions approximated simple structure, with high loadings of items intended as solicitous and empathic on one factor and high loadings of punishing items on the other factor. Some items weakly cross-loaded onto the opposite factor in the negative direction. As expected, adding a third factor to both within- and between-person levels improved model fit from the two-factor solution ($X^2(16) = 186.7, p < .05$). For this reason and because of the conceptual precedent, the three-factor solution was chosen as the final solution.

**Patient physical function.** The Short Physical Performance Battery (Guralnik et al., 1994) was administered by an interviewer to assess balance, gait speed, and chair rises at T1, T2, and T3 by the ability to stand with feet in a tandem position, time to walk eight feet, and time to alternate standing and sitting in a chair with five repetitions. The scale ranges from 0 to 12 with higher scores indicating better physical performance. Performance of these tasks has strong predictive validity with the ability to independently carry out activities of daily living, the likelihood of institutionalization, rehospitalization after discharge, and mortality (Guralnik et al., 2000; Volpato et al., 2011).

**Covariates.** Covariates for the multilevel model were chosen on a conceptual basis. The lagged spouse responses (i.e., from the previous day) were included in each model to allow us to conclude that same-day pain expressions and spouse responses were related above and beyond stability in responses across days (Larson & Almeida, 1999). Because patients’ experience of pain serves as an interpretive backdrop that may color their perceptions of spouse responses, patient reports of pain were included as an important covariate (Stephens et al., 2006). Patient pain severity was assessed with one item at end-of-day in the daily diary: “How would you describe your overall arthritis pain today?” Responses ranged from 0 (none) to 3 (severe). The growth-curve component of the model covaried for person-level means of
daily pain expression and spouse response to allow conclusions regarding the role of expression-response coupling above and beyond individual levels of pain expression and spouse response.

**Data Reduction and Analysis**

In preparation for data analysis, daily predictors and covariates were person-mean centered. Between-person predictors were grand-mean centered. Next, a series of multilevel models were fit using Mplus to test random slope variance for the three combinations of verbal pain expression with punishing, empathic, and solicitous responses. For models with significant random slope variance in daily coupling, multilevel growth models with a latent coupling term were estimated. Assigning a latent variable to the coupling term that subsumes estimates of daily associations, as shown in Figure 1, serves as a more powerful alternative to a two-step approach of multilevel model estimation and slope outputting for use in other models (Raudenbush & Sampson, 1999). Time scores were set to 0, 1, and 3 to index a linear trend with the three unequally spaced interview occasions, T1 (baseline), T2 (6 months from baseline), and T3 (18 months from baseline).

According to our hypothesis, slope estimates were expected to be significant—positive for empathic responsiveness and negative for solicitous and punishing responsiveness. No specific predictions were made for the association between spouse responsiveness and the intercept parameter, which represents concurrent physical function. A significant association between responsiveness and change in physical function (i.e. the slope) along with a null association between responsiveness and baseline physical function (i.e. the intercept) would suggest that the effects of spouse responsiveness patterns take time to manifest and that responsiveness itself may be time-varying. A significant link between responsiveness and the slope paired with a significant intercept association would indicate stability of spouse responsiveness over time, as the most recent diagnosis was one year prior to the study, or an
immediate effect on physical function, a less likely possibility. Models are represented by the following set of equations:

\[
\text{SpResponse}_{ti} = \gamma_0 + \gamma_{10}\text{PainExpress}_{c}\text{c}_{ti} + \gamma_{20}\text{SpResponseLag}_{c}\text{c}_{ti} + \gamma_{30}\text{OverallPain}_{c}\text{c}_{ti} + u_{0i} + \\
\beta_1\text{PainExpress}_{ti} + \epsilon_{ti}
\]

\[
\text{PhysicalFunction}_{ti} = \beta_0 + \beta_1\text{Time}_{ti} + \beta_2\text{Coupling}_{i} + \beta_3\text{PainExpress}_{i} + \beta_4\text{SpResponse}_{i} + \\
\beta_6\text{TimeXCoupling}_{i}
\]

**Results**

**Multilevel Models**

Multilevel models for empathic, solicitous, and punishing responses were examined to confirm significant variability in the expression-response random slopes before relating the terms to longitudinal change in patient physical function. Fixed slopes, or average sample-level associations, were not of interest in the present study. All three models converged, and solutions were positive definite. Empathic and solicitous models both showed significant variance in the random slope (\(\sigma^2_{\text{Empathic}} = 0.22, SE = 0.06, p = .001; \sigma^2_{\text{Solicitous}} = 0.18, SE = 0.08, p = .017\)). Because the random slope variance was not statistically significant in the punishing model (\(p = .782\)), it was excluded from further analysis.

**Latent Variable Multilevel Growth Curves**

The growth curve model of physical function was first estimated without predictors. On average, patients’ linear trends of physical function were not significantly different from zero (\(p = .152\)). Nevertheless, there was significant variability in initial physical function (\(\sigma^2 = 3.54, SE = 0.13, p < .0001\)) as well as variability in change across the 18-month study period (\(\sigma^2 = 0.11, SE = 0.03, p = .001\)).

**Empathic model.** As shown in Table 2, expression-empathic daily coupling did explain significant variance of linear change in physical function across the 18-month follow-up period, above and beyond average levels of pain expression and empathic spouse responses (Estimate = 0.31, SE = 0.15, \(p = .031\)). That is, patients in dyads who had more positive daily expression-
empathic response coupling also showed steeper linear improvements in physical function across 6 and 18 months. More specifically, patients whose spouses were 1 SD above the mean on empathic responsiveness improved 0.24 points in their physical function over 18 months, whereas patients whose spouses were 1 SD below the mean on empathic responsiveness made a gain of 0.04. Expression-empathic daily coupling did not significantly relate to initial levels of patient physical function ($p = .115$).

**Solicitous model.** Expression-solicitous coupling did not significantly relate to initial levels ($p = .141$) or prospective changes ($p = .663$) in patient physical function (see Table 3).

**Discussion**

Models of daily experience that articulate the cumulative effects of everyday interpersonal hassles and uplifts may be able to explain the well-established impact of intimate relationships on physical health. This perspective is rooted in more general developmental metatheories of how change on smaller time scales propagates to produce gradual shifts over macro time scales (Gerstorf et al., 2014; Magnusson & Cairns, 1996). However, very little work has empirically demonstrated that any kind of daily experience influences long-term changes in health (Piazza et al., 2013; Ross et al., 2011), and none have shown the link for everyday interactions in couples. The question of whether daily relational processes relate to prospective changes in physical health was addressed in a chronic pain sample due to its status as a widely studied support context and prevalence as a public health concern. In support of our hypothesis, patients whose spouses were more empathically responsive to pain expression in daily life demonstrated better physical function 18 months later than patients whose spouses were less empathically responsive. The opposite was expected for solicitous and punishing responsiveness, but neither effect was significant. To our knowledge, this study is the first to link patterns of couples’ day-to-day conversations to prospective changes in an objective clinical endpoint. The strengths of this novel finding as well as potential explanations for null associations are discussed.
Several features of the current study make the finding for daily empathic spouse responsiveness a unique contribution. The multitemporal design that combined daily diary and longitudinal components in a temporally ordered way captures the metatheoretical notion that daily experiences accrue and lead to slower shifts in trajectory over the long-term (P. B. Baltes, Lindenberger, & Staudinger, 2006; Magnusson & Cairns, 1996). The fact that couples’ daily interactions preceded assessments of physical function clearly establishes temporal sequence. Furthermore, empathic responsiveness was not significantly associated with baseline physical function, evidencing that the effect of daily pain communication is time-ordered, not merely due to longstanding individual differences in couples. Indeed, the finding indicates that daily empathic spouse responsiveness is a dynamic, or time-varying, process with effects that take time to manifest. Also, having objectively assessed physical function over time allowed us to draw conclusions about the practical long-term implications of couples’ daily pain communication for health. Patterns of couples’ interactions related to changes in how fast participants walked, how well they maintained balance, and how fluidly they rose from a chair unassisted. Performance of these tasks predicts the ability to independently carry out activities of daily living, the likelihood of institutionalization, rehospitalization after discharge, and mortality (Guralnik et al., 2000; Volpato et al., 2011). Couples’ daily communication was assessed in a 22-day sampling of perceived illness-specific communication behaviors from both patient and spouse (as recommended in seminal reviews, Leonard, Cano, & Johansen, 2006; Robles et al., 2014). Using spouses’ reports of patient pain expression and patients’ reports of spouse responses reduced shared reporter variance and captured the transactional nature of communication (Hadjistavropoulos et al., 2011).

Daily spouse responsiveness, indexed with couple-specific slopes, emerged as a distinct construct that explained significant variance in physical function trajectories above and beyond person-level averages of pain expression and spouse response. In fact, daily empathic spouse responses were not a significant contributor to change in physical function when
responsiveness was excluded from the model. That is, empathic responses arose as promotive of physical function only within the context of expression. In this study, daily responsiveness reflects a dyadic pattern that captures the calibration of spouse empathic behavior to pain cues. This dynamic construct shares overlap with but also diverges from responsiveness as studied in other contexts of attachment relationships (Ainsworth, 1969; Bodenmann et al., 2015; Reis & Shaver, 1988). Responsiveness in intimate adult relationships and parent-child dyads has been defined as the proclivity to respond to the other's bids in an appropriate and timely, or “sensitive,” way (Ainsworth, 1969). In the adult literature, perceived partner responsiveness has typically been studied cross-sectionally (Burleson et al., 1994; Manne, Ostroff, et al., 2004; Reis & Shaver, 1988), however. For an exception, see Maisel and Gable (2009). Unlike previous studies of responsiveness in adult relationships, our operationalization of daily responsiveness explicitly linked the response to the request in a dyadic variable and captured the dynamics of interaction across multiple days in everyday life. Also, we examined each domain of responsiveness separately, having hypothesized different effects by response type.

Contrary to hypothesis, daily solicitous responsiveness did not significantly relate to prospective declines in physical function, though the estimate was in the expected direction. Excessive instrumental support may challenge efficacy and discourage patients from attempting tasks independently (M. M. Baltes & Wahl, 1996; Martire et al., 2002), but patients likely differ in whether or not they experience an offer of support as disproportionate to their needs. Patterns of solicitous responsiveness that are highly unstable over the course of months and years may account for the null effect; that is, generally, spouses who are very solicitously responsive at one time may not be so at another time if help is being titrated to patients’ fluctuating needs.

Our hypothesis could not be tested for punishing responsiveness as there was inadequate variability in daily spouse punishing responsiveness. Daily punishing responses were low on average and fluctuated very little. Indeed, the couples in our sample, who had
been married for 35 years on average, reported high levels of marital satisfaction (i.e., an average of 39 points on a 50 point scale) and likely avoided highly turbulent daily patterns.

The present study includes limitations. As noted previously, we were not able to assess the impact of punishing responsiveness on physical function due to low variance. Future studies should seek to capture a wider range of negative spouse responses in daily interaction and recruit samples of couples with greater variability in marital satisfaction. Also, daily spouse responsiveness was operationalized in terms of same-day associations between pain expression and spouse responses and, therefore, temporal sequence of expression and response within the day cannot be confirmed. Models included spouse responses during the previous day to strengthen interpretation; future work could be aimed at capturing pain expression and spouse responses in the moment in order to make definitive conclusions about temporal order. Next, results suggest that spouse responsiveness may be a time-varying phenomenon instead of a stable trait of the dyad or the spouse, but this cannot be concluded with certainty as only one 22-day period was sampled. A measurement burst design that includes two or more intensive longitudinal assessment periods could address the issue directly.

The current study demonstrates that couples’ everyday interactions impact long-term trajectories of objectively assessed physical function. Conclusions are enhanced by the external validity of experience sampling and the temporal sequence of the longitudinal design. Daily spouse responsiveness, captured using within-person slopes, is a unique relational construct that reflects important interpersonal processes that arise in the everyday lives of couples. Findings support a dynamic developmental perspective which suggests that seemingly small and mundane exchanges assemble into longer patterns of interaction that over days, weeks, months, and years accrue to wield measurable impacts on physical health and function. Future studies should test whether daily support communication is relevant for couples’ long-term health in other disease contexts and healthy populations.
Table 1

**Demographic Characteristics of Patients and Spouses (N = 145)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients</th>
<th>Spouses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>65.6 (9.8)</td>
<td>65.3 (11.5)</td>
</tr>
<tr>
<td>Male gender</td>
<td>43%</td>
<td>58%</td>
</tr>
<tr>
<td>White race</td>
<td>88%</td>
<td>86%</td>
</tr>
<tr>
<td>Years of education</td>
<td>16.1 (2.0)</td>
<td>15.9 (2.1)</td>
</tr>
<tr>
<td>Full-time employment</td>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>Duration of knee OA (years)</td>
<td>12.6 (11.3)</td>
<td></td>
</tr>
<tr>
<td>Household income</td>
<td>$40,000-59,000</td>
<td></td>
</tr>
<tr>
<td>Years married/in relationship</td>
<td>34.3 (16.6)</td>
<td></td>
</tr>
<tr>
<td>Marital satisfaction</td>
<td>39.61 (6.26)</td>
<td>38.94 (6.47)</td>
</tr>
</tbody>
</table>

*Note.* Full-time employment status was defined as typically working 30 hours or more per week. Marital satisfaction was assessed with the 10-item dyadic satisfaction subscale of the Dyadic Adjustment Scale, whose scores range 0 - 50 (Spanier, 1976). OA = osteoarthritis. M = mean. SD = standard deviation.
Table 2

Latent Variable Growth Curve of Patient Physical Function Predicted by Empathic Responsiveness, Pain Expression, and Empathic Responses

<table>
<thead>
<tr>
<th>Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsiveness</td>
<td>0.853</td>
<td>0.541</td>
<td>.115</td>
</tr>
<tr>
<td>Pain expression</td>
<td>-0.927</td>
<td>0.475</td>
<td>.051</td>
</tr>
<tr>
<td>Empathic response</td>
<td>-0.266</td>
<td>0.113</td>
<td>.018</td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Empathic coupling</td>
<td>0.311</td>
<td>0.145</td>
<td>.031</td>
</tr>
<tr>
<td>Pain expression</td>
<td>-0.155</td>
<td>0.159</td>
<td>.329</td>
</tr>
<tr>
<td>Empathic response</td>
<td>0.040</td>
<td>0.041</td>
<td>.330</td>
</tr>
</tbody>
</table>

Note. N = 145
Table 3

*Latent Variable Growth Curve of Patient Physical Function Predicted by Solicitous Responsiveness, Pain Expression, and Solicitous Responses*

<table>
<thead>
<tr>
<th>Effect</th>
<th>Estimate</th>
<th>SE</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsiveness</td>
<td>1.149</td>
<td>0.780</td>
<td>.141</td>
</tr>
<tr>
<td>Pain expression</td>
<td>-0.795</td>
<td>0.485</td>
<td>.101</td>
</tr>
<tr>
<td>Solicitous response</td>
<td>-0.473</td>
<td>0.158</td>
<td>.003</td>
</tr>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solicitous coupling</td>
<td>-0.095</td>
<td>0.217</td>
<td>.663</td>
</tr>
<tr>
<td>Pain expression</td>
<td>-0.115</td>
<td>0.156</td>
<td>.459</td>
</tr>
<tr>
<td>Solicitous response</td>
<td>0.024</td>
<td>0.049</td>
<td>.627</td>
</tr>
</tbody>
</table>

*Note. N = 145*
Figure 1. Schematic representation of the model used to test the present study's primary research questions
Chapter 4

Discussion

The overall objective of the current studies was to elucidate the health consequences of daily pain communication for patients with chronic pain and their spouses. The first study examined spouse parasympathetic reactivity to patient RA symptom expression using audio recordings and ambulatory cardiac assessment in couples’ homes. Consistent with lab-based findings with autonomic measures, it was expected that spouses would lift the vagal brake to allow for an increase in arousal (HR) in response to patient symptom expression. The second study investigated the long-term impact of daily patterns of pain expression and spouse response on objectively measured patient physical function. It was predicted that patients whose spouses were more empathically responsive to verbal pain expression in day-to-day interaction would experience better physical function than those whose spouses were less empathically responsive. The opposite was expected for solicitous and punishing responsiveness.

Contrary to hypothesis, in the first study spouse RSA augmented in response to patient symptom expression, congruent with enhanced social engagement and successful emotion regulation, and HR did not decrease, indicating no change in physiological arousal. Thus, in a generally close, well-functioning couple whose patient had severe, newly diagnosed disease, the spouse seemed to successfully regulate himself in the face of the patient’s verbal pain signals, avoiding resource-expensive stress responses. The ability to generalize this finding to other couples in different circumstances is limited, and the evidence does not warrant deposing theory. However, this study does reject the conjecture that vagal suppression and heightened physiological arousal are inevitable in response to patient suffering in daily life. In partial support of the second study’s hypotheses, patients whose spouses were more empathically responsive to daily pain expression improved in their physical function across 18 months. Solicitous responsiveness did not relate systematically to long-term changes in physical
function, and between-person differences in punishing responsiveness lacked sufficient variability to be tested as increases in punishing spouse responses were rare.

Together, the two studies illustrate the proximal and distal health implications of couples’ daily functioning in chronic pain. Themes and issues common to these studies are discussed, including spouse responsiveness, the patterns that link daily phenomena to long-term change, design considerations, limitations, and future directions.

**Spouse Responses and Responsiveness**

Spouse responses, physiological and behavioral, are central to pain communication and to both partners’ health. Allowing for exploration and engagement when the environment is deemed safe (Thayer & Lane, 2000), post-expression increases in RSA bolster spouses’ social attunement, which may facilitate empathic behaviors. In turn, as an act of behavioral regulation or self-soothing, providing support should reinforce vagal augmentation and promote a state of physiological calm. Indeed, spouse responses would be considered a form of situation modification, an antecedent-focused regulative strategy (Sheppes & Gross, 2011) that is resource-efficient and effective for managing emotional reactions.

Mutual influences, or *coactions* (Gottlieb, 1996), of physiological and behavioral responses likely underlie empathic spouse responsiveness to pain expression, readying the spouse to respond sensitively to the patient and adaptively managing the potential cost of a potent network stressor to the spouse him or herself (Almeida et al., 2002). Sensitively delivered, appropriately scaffolded support may directly allay patient pain through the analgesic effects of oxytocin (Ditzen et al., 2009) and encourage health-promotive behaviors in patients without challenging efficacy, thus aiding physical function. As well, helping behaviors and underlying affiliation motivation have been found to promote positive affect in the support provider (Poulin et al., 2010), suppress HPA activity through increases in progesterone (S. L. Brown, Fredrickson, et al., 2009; Patchev, Hassan, Holsboer, & Almeida, 1996; Wirth &
The current pair of studies addresses a few such questions. The second study revealed that an expression-response pattern from a 22-day sampling of daily life did not have immediate impact on physical function, but rather took months to manifest. On the other hand, the parasympathetic consequences of symptom expression was rapid, as spouse changes in RSA
rose and subsided in fewer than 5 minutes. Establishing points of reference in the temporal
course of events is one useful step toward understanding the theories of change that govern the
link between couples’ daily experiences and longer health trajectories.

Taken together, the results may point to salubrious patterns, as physiological and
behavioral spouse responses contribute to a positive feedback loop, serving a maintenance
function (Gottlieb, 1996) for spouse responsiveness—potentially a beneficial homeostatic cycle
for both partners. Or, if vagal augmentation drives sympathetic activity by encouraging
continued engagement with stressful stimuli, spouses’ health could suffer. Alternatively,
augmentation may represent a pattern common to the early stages of disease adaptation that
spouses cannot maintain over the course of years. Some work has suggested that social support
eventually deteriorates (Bolger et al., 1996), perhaps because costs begin to incur for spouses.
Moreover, perturbations, or fluctuating circumstances of daily life, may derail patterns of
responsiveness. Being confronted with expression of patient pain and suffering when self-
regulatory resources are scarce may result in protracted stress responses and punitive
behaviors. Depending on the broader risk profile or level of cumulative risk, maladaptive
patterns may escalate (Butler, 2011) and become instantiated, or they may resolve. Given the
complex dynamics of daily life, it is impossible to know from these studies what patterns will be
maintained in the long-term. Future work should seek to explicitly test these theories of change
by examining spousal parasympathetic and sympathetic reactivity over weeks and months, and
by capturing multiple periods of daily assessments over months and years.

The Value of Studying Life as it is Lived

Our understanding of pain communication’s effects on spouse cardiovascular reactivity
and patient physical function has been based largely on experimental and cross-sectional
studies. Thus, little has been known about how frequently patients express their pain in daily
life and, therefore, how relevant experimental paradigms are for daily life, as well as how
spouses respond physiologically and over what time course. Also, conclusions about the impact
of spouse responses to pain on patient physical function have been confounded by the bidirectional likelihood that the level of physical function can determine the level of spouse response required.

The three patients in the first study varied in their frequency of RA-related physical symptom expression—none, on average 3 times per day, and an average of 11 times daily. Therefore, spouses were presented with different numbers of opportunities to react to pain expression. If reactivity to verbal symptom expression is a highly specific mechanism, it may be that spouses whose partners do not express pain are protected in part from the well-established risk of caregiving. On the other hand, if reactivity demonstrated in the lab reflects a more general response style to stressors, the risk would remain but fail to be captured by a focus on symptom expression.

Further, though theories suggest that spouse responses impact patient disability, cross-sectional survey studies have obscured temporal sequence, and sequential analyses of couple interactions have extrapolated links between spouse response and immediately subsequent pain expression to long-term effects on patient physical function. Our longitudinal study captured the temporal sequence of the association by assessing daily pain expression and spouse response and following changes in patients' physical function over 18 months. Based on this design, it can be concluded that daily empathic spouse responsiveness relates to later improvement in patient physical function.

Limitations

Conclusions drawn from these studies must be qualified by their limitations. First, nonverbal expression, likely integral to the pain communication process, was not considered. Spouses may undergo more severe physiological reactions to nonverbal pain expression than to verbal expression. Craig and colleagues (2010) hypothesized a congruence model, wherein “automatic” or nonverbal expressions of pain are more likely to be met with involuntary aversive responses in the observer, evolutionarily instantiated reactions to threats (Simon et al.,
Despite the great likelihood that nonverbal and verbal expressions, in fact, often co-occur and, therefore, that nonverbal responses were indirectly captured in both studies, effects may not generalize to scenarios when nonverbal and verbal expressions do not arise together. For instance, it was found that on days when verbal pain expression is high, the links between daily nonverbal pain expression and empathic and solicitous spouse responses are more positive than when verbal pain expression is low (Wilson et al., 2013). Conversely, high daily verbal pain expression buffers the association between nonverbal pain expression and punishing spouse responses in daily interaction.

Though the current studies advance our understanding of the processes by which daily pain communication affects couples’ health, some analytic and design attributes limited the extent to which conclusions can be drawn. For example, spouse parasympathetic reactivity was defined as the pre- to post-expression change in RSA. It did not take into account the shape of the onset and decay of the response, as well as how the time elapse between responses may impact the response curve itself. Also, the study of spouse responsiveness relied on daily summations of pain expression and spouse response; momentary reports may capture more variability in solicitous and punishing responsiveness and, therefore, reveal associations with changes in physical function.

Last, the current studies may lack generalizability to other couples. The first study examined an unusually small sample of couples; potentially important between-couple factors such as time-from-diagnosis, overall disease severity, couples’ illness beliefs, and spouse regulatory capacity and communication efficacy could only be speculated about. The second study included couples who on average had been happily married and managing arthritis for many years. It is unclear how daily pain communication would impact trajectories of physical function in poorly adjusted couples.
Conclusion

The current studies sought to integrate and advance our understanding of the proximal and distal processes that lead couples’ everyday pain communication to affect both partners’ health. Instead of vagal suppression and increased arousal, vagal augmentation and no change in HR were found to be one spouse’s response to patient symptom expression in everyday life, which begs follow-up questions about the mechanisms of spousal caregivers’ heightened risk for cardiovascular disease. Also, the second study established the first piece of empirical evidence that couples’ daily interactions play a role in longer health trajectories. Specifically, daily empathic spouse responsiveness to patient verbal pain expression related to long-term improvements in patient physical function.

To further probe the proximal mechanisms of spouses’ health risk, future studies should capture nonverbal expression with video streams, as well as implement audio recording techniques to measure vocal quality and fundamental frequency, a vocal index of physiological arousal (Simonov & Frolov, 1973), by separating participants’ voices from background noise. To track the full cardiovascular response to pain expression, pre-ejection period (PEP), an index of sympathetic reactivity, should also be measured (Cacioppo, Uchino, & Bernston, 1994). In-depth qualitative analysis of couples’ conversations would improve coding schemes by illuminating the strategies patients and spouses use to convey information and develop mutual understandings about the illness without explicitly discussing it. Also, the study of pain and symptom expression should be juxtaposed with an examination of other kinds of daily interactions and experience to establish their relative impact.

Future work should elucidate the mechanisms of the effect of spouse responsiveness on long-term patient physical function. Proximal mechanisms may include immediate rises in oxytocin, which may have a direct analgesic effect, and distal mechanisms could include fluctuations in self-efficacy. Also, measurement burst designs could assess the time-varying nature of responsiveness patterns and situate the relative effects of changes in patterns.
References


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Vita
Stephanie J. Wilson

EDUCATION

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<td>05/2009</td>
<td>Psychology</td>
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<tr>
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HONORS AND AWARDS

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PAPERS AND CHAPTERS


