CORTISOL SYNCHRONY IN OLDER COUPLES:

LINKS WITH DIFFERENTIAL CONTEXTS, INDIVIDUAL CHARACTERISTICS, AND LONG-TERM OUTCOMES

by

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Abstract

For a lot of older adults, the relationship with a significant other is a fundamental social context that structures their daily life and interactions. This research program investigated everyday interpersonal physiological dynamics that may contribute to intertwined health trajectories in old age. In particular, it focused on interconnected fluctuations of the stress hormone cortisol (cortisol synchrony) because dysregulated cortisol secretion has been linked with significant health risks. It utilized three samples of older adult couples (N = 322 couples), who provided multiple salivary cortisol samples and concurrent electronic assessments for a 7-day period, as they went about their daily lives. Study 1 aimed to illuminate daily life situations (proximal contexts) and pertinent individual differences that may be associated with more pronounced cortisol synchrony in older couples. Cortisol synchrony was higher in moments when the partner was present and when individuals reported prior positive socio-emotional partner interactions. Furthermore, greater self-reported perspective taking tended to be linked with greater cortisol synchrony. Building on these findings, Study 2 aimed to better understand long-term risks and benefits of being ‘in sync’. Among wives, higher cortisol synchrony was associated with a stronger increase in relationship satisfaction but also a stronger increase in cardiovascular risk over time, as indexed by non-high density lipoprotein (HDL) cholesterol levels. For husbands, higher cortisol synchrony was not significantly associated with changes in relationship satisfaction or non-HDL cholesterol levels over time, but it was linked with higher initial non-HDL cholesterol levels. Study 3 adopted a macro perspective, taking a step back to examine broader socio-political correlates of cortisol synchrony in older couples. The extent of cortisol synchrony was moderated by macro-context, such that couples living in a German federal state that was placed further right on the left-right political ideological spectrum exhibited greater cortisol synchrony. This line of research emphasizes that older romantic partners are deeply intertwined in daily processes relevant for health. It unpacks key proximal and distal correlates of everyday cortisol synchrony, identifies individual differences relevant to such dynamics, and points to potential adaptive and maladaptive long-term implications of cortisol synchrony for relationship functioning and health.

Lay Summary

Individuals tend to show synchronized ups and downs of their stress hormones (such as cortisol) with close others in their daily lives. This research program uses data of a total of 322 older couples who provided saliva samples at home to better understand interconnections in cortisol levels (cortisol synchrony). Study 1 found that cortisol synchrony was higher when the partner was close by and when older partners had a previous positive interaction with one another. Furthermore, cortisol synchrony was more pronounced in individuals who are better able at taking someone else's perspective. Study 2 showed that cortisol synchrony may have relationship benefits, but that it may also come with a cost for both partners' health. Study 3 emphasized that the political context may be tied to daily cortisol dynamics in older couples. Findings help better understand the everyday dynamics that contribute to health being linked in older couples.

Preface

With support of my advisor, Dr. Christiane Hoppmann, I was responsible for the design of this PhD research program. Formulation of all research questions and analyses of data reported herein were performed by me, with guidance from Dr. Hoppmann. I developed a theoretical framework on dyadic synchrony across the adult lifespan, which is currently submitted for publication and which guided the theoretical development of the present thesis. Additionally, I developed a data handling and cleaning procedure for daily life cortisol data in collaboration with my advisor, which was published in the Oxford Research Encyclopedia of Psychology: *Hoppmann, C. A., Pauly, T., Michalowski, V. I., & Nater, U. M. (2018). Everyday salivary cortisol as a biomarker method in lifespan developmental methodology. In Oxford Research Encyclopedia of Psychology. Oxford University Press*. I was responsible for cortisol data processing for the Linked Lives (LL) project and consulted on cortisol processing for the remaining two data sets.

I am the primary author and contributor to this dissertation (Chapters 1-5). Chapters 2, 3, and 4 were adapted from manuscripts under review or prepared for publication (details below). Chapters 1 and 5 are partly based on the following conceptual article: *Pauly, T., Gerstorf, D., Wahl, H.-W., & Hoppmann, C. A. (in preparation). A developmental-contextual model of dyadic synchrony across adulthood and old age*.

Findings reported in Chapter 2 were accepted for publication: *Pauly, T., Michalowski, V. I., Drewelies, J., Gerstorf, D., Ashe, M. C., Madden, K. M., & Hoppmann, C. A. (in press). Cortisol synchrony in older couples: Daily socio-emotional correlates and interpersonal differences*. *Psychosomatic Medicine*. This manuscript is based on data from two projects, the LL project and the Berlin Couple Dynamics (BCD) project. Christiane Hoppmann, Denis Gerstorf, Maureen Ashe, and Kenneth Madden were responsible for study conception for the LL project; Christiane Hoppmann and Denis Gerstorf were also responsible for study conception for the BCD project. Victoria Michalowski coordinated data collection for the LL project. Johanna Drewelies coordinated data collection for the BCD project and processed cortisol data. I am lead author of this publication and was responsible for reviewing the relevant literature, formulation of the research hypotheses, conducting the statistical analyses, and writing a first draft of the manuscript. Victoria Michalowski, Johanna Drewelies, Denis Gerstorf, Maureen Ashe, Kenneth Madden, and Christiane Hoppmann contributed to revising the manuscript.

A version of Chapter 3 is under review for publication: *Pauly, T., Gerstorf, D., Ashe, M. C., Madden, K. M., & Hoppmann, C. A. (under review). You're under my skin: Long-term relationship and health correlates of cortisol synchrony in older couples.* This manuscript utilizes the longitudinal component of the above-mentioned LL project. I took lead in formulating the research question, developing an appropriate statistical modeling approach for dyadic longitudinal data, conducting analyses, and drafting the manuscript. Denis Gerstorf provided consultation on statistical models. Christiane Hoppmann, Denis Gerstorf, Maureen Ashe, and Kenneth Madden assisted with interpretation and manuscript revisions.

Results presented in Chapter 4 are submitted for publication: *Pauly, T., Kolodziejczak, K., Drewelies, J., Gerstorf, D., Ram, N., & Hoppmann, C. A. (under review). Political context is associated with everyday physiological linkage in older couples*. Denis Gerstorf and Christiane Hoppmann were responsible for study conception and Karolina Kolodziezjak was responsible for study coordination of the Everyday Life of Older Couples (ELOC) project. I was responsible for designing research hypotheses and for selecting and coding public data on German federal states. I was further responsible for data analysis/interpretation and composing the first manuscript draft. Johanna Drewelies and Karolina Kolodziezjak processed cortisol data. Karolina Kolodziezjak, Johanna Drewelies, Denis Gerstorf, Nilam Ram, and Christiane Hoppmann assisted with interpretation and manuscript revisions.

All research presented in this dissertation was ethics approved. The LL project (Chapter 2 & Chapter 3) was approved by the Clinical Research Ethics Board of the University of British Columbia, # H12-01854. The BCD project (Chapter 2) and the ELOC project (Chapter 4) were approved by the research ethics board of the Humboldt-University Berlin (#2013-15). Secondary analysis of data of both projects was approved by the Behavioural Ethics Board of the University of British Columbia (BCD project: #H18-01490, ELOC project: #H19-02893).

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BCD	Berlin Couple Dynamics
CI	Confidence Interval
ELOC	Everyday Life of Older Couples
HDL	High-Density Lipoprotein
HPA	Hypothalamic Pituitary Adrenal
IRI	Interpersonal Reactivity Index
LL	Linked Lives
L-R	Left-Right
MARPOR	Manifesto Research on Political Representation
NA	Not Applicable
RAS	Relationship Assessment Scale
SD	Standard Deviation
SE	Standard Error
SOEP	SOcio-Economic Panel

Acknowledgements

Thanks to Christiane, for taking me in as a visiting student and then giving me the opportunity to return for 4 years of graduate school. Thanks for all the support, encouragement, and advice. Thanks for being such a great role model and teaching me the importance of always following your principles, of building relationships, and guiding me in navigating the sometimes complicated world of academia. I can't express how grateful I am for the opportunity to have worked (and hopefully continue to work) with you. Also particular thanks to my committee, for their probing questions and helpful feedback.

Thanks to the other graduate students in the lab. Jenn and Victoria: When joining the lab I very much looked up to both of you and strived for becoming as awesome a researcher and person in general, as both of you are. Thanks for the company, shared struggles, office conversations, and not just being colleagues, but also becoming friends. I sincerely hope we will all stay in touch. Also thanks to the other Psych grad students, to Siba, Patrick, Pavel, Charlotte, Yeeun, and many others. We certainly are/were in this journey together and it was so much more fun to not follow this path by myself but to share it with such an amazing group of people.

Thanks to Stella, Izzie, Anna, Harry, Chris, and the rest of the PULSE team. We shared a lot of uplifts and challenges conducting this time-intensive study. This would not have been possible without all of your help, particularly from Stella. I do not think I would have finished my thesis, if it would not have been for Stella stepping up to take over coordinating tasks from me for a while. Thanks for the commitment that went way beyond what can be expected – be it working long hours during trips to the Island or the Lower Mainland or be it dropping everything to bring us equipment we accidentally forgot in the lab on a Friday night. We had so much fun: Driving throughout BC and squeezing in the occasional hike, successfully exiting escape rooms, snowshoeing, and racing the Sun Run in the hail come to mind. I am deeply grateful for getting to know you and to have been part of your time at UBC. Thanks to the PULSE interns, to Lea, Magdalena, Phileas, and Johanna. Your contributions while joining our team for a while freed up a significant amount of my time that I could then dedicate to the research presented in this thesis. Finally, thanks to the lab members in general for the occasional chat, shared meals, and lively paper discussions in lab meetings sparking new ideas.

Thanks to Jan/Nina and Karolina/Denis for working closely on projects and giving me the opportunity to extend my horizon. During my time in Berlin and during Jan's and Karolina's stay here in Vancouver I got to connect with and learn from such outstanding researchers. A lot of thoughts manifested in this thesis were inspired by our joint work and conversations. Not just at university, but also while going on a trip to Whistler or on top of the Harbor Centre post Urban Grind. Karolina deserves special gratitude for the immense support with data for Chapter 4.

Thanks to everyone who provided me with financial support for my studies: UBC, the Heart and Stroke Foundation of Canada, the Studienstiftung, and the Li Tze Fong Fellowship.

I also don't want to end without saying thanks to the participants. Taking part in the kind of studies that constitute this thesis requires a lot of time and commitment. I sincerely appreciate their contributions and a lot of them went way beyond what was expected. Some insights were certainly gained during casual conversations post-session drinking tea in the garden.

Last but not least, thanks to my family and friends, for always being there. Taking breaks in the mountains, leaving all technology and worries behind, provided me with well-needed recovery time. Thanks for the never-ending encouragement and trust that I can accomplish anything I set my mind to. Thanks for helping me build the strength that was required to conquer the challenges of graduate school. I could not have done it without you.

Chapter 1: Introduction

1.1. Social relationships, health, and aging

As humans, we interact with others on an almost daily basis. Social relationships are not just an important part of the human experience, they are in fact at its core. As the Dalai Lama XIV (2012) points out:

> *We human beings are social beings. We come into the world as the result of others' actions. We survive here in dependence on others. Whether we like it or not, there is hardly a moment of our lives when we do not benefit from others' activities. So it is hardly surprising that most of our happiness arises in the context of our relationships with others.* (p. 22)

There is a large amount of research demonstrating that social relationships matter: High quality social relationships boost health and wellbeing (Kawachi & Berkman, 2001; Seeman, 1996), whereas negative aspects of social relationships such as conflict, rejection, and criticism can cause serious harm (Robles & Kiecolt-Glaser, 2003; Umberson & Montez, 2010). The structure and importance of our social networks change across the adult lifespan. There are two time periods during which we particularly rely on close others. The first one is childhood, during which we could not survive without parental care. The second one is older adulthood. When confronted with age-normative declines in resources, we once again increasingly rely on other people for support (P. B. Baltes et al., 1999). Whereas younger adults prize independence and autonomy, older adults are hypothesized to prioritize meaningful relationships and they recruit the help of other people to accomplish what may not (or no longer) be possible alone (M. M. Baltes & Carstensen, 1999; Hoppmann & Gerstorf, 2016). Furthermore, with decreasing perceptions of time left in life, older adults are hypothesized to place more importance on maintaining positive social relationships with close others (Carstensen et al., 2003; Fingerman & Charles, 2010). Older adults interact more with close social partners such as their spouse, and derive more satisfaction from these interactions (Carstensen, 1992). On the flipside, negative effects of marital strain on physical health grow stronger as individuals get older (Umberson et al., 2006).

Compared with other social partners, the relationship with a romantic partner holds particular significance for an individual's health (Kiecolt-Glaser & Newton, 2001; Slatcher & Selcuk, 2017). Speaking to the importance of spousal interrelations in older adults, developmental trajectories in health and well-being are closely linked in old couples (Hoppmann & Gerstorf, 2009). For example, a meta-analysis has demonstrated that the presence of coronary risk factors including hypertension, smoking, diabetes, and obesity was significantly linked to the cardiovascular health status of the partner, with odds ratios ranging from 1.16 to 3.25 (Di Castelnuovo et al., 2009). Although most prior research on spousal health links is cross-sectional, longitudinal studies have started to show that changes in health and health behaviours over time are interrelated in romantic partners (Chiu & Lin, 2019; Cobb et al., 2016; Jackson et al., 2015). For example, following a sample of 3,889 couples over a period of up to 25 years, Cobb et al. (2016) found that an individuals' risk of becoming obese doubled when their partner became obese. Several factors may contribute to such health concordance in older couples. Individuals tend to enter relationships with individuals with similar characteristics (assortative mating; Luo, 2017). Furthermore, they tend to share the same resources (e.g. family support network) and to be exposed to the same stressors (e.g. financial hardship; K. R. Smith & Zick, 1994). However, researchers have demonstrated that health linkages can be explained by mechanisms that go beyond assortative mating and shared environments, including convergence in health behaviours and interpersonal interactions (Ask et al., 2012; Davillas & Pudney, 2017; S. E. Wilson, 2002). How exactly does this influence of social relationships on health play out in daily life? I argue that we need to shine the theoretical spotlight onto couples' ***everyday lives*** in order to offer insights into the underlying social dynamics and how older romantic partners get under each other's skin to shape linked longer-term health trajectories.

1.2. The importance of studying micro-processes

A large share of studies on social relationships and health are based on cross-sectional and longitudinal data sets. However, long-term changes in health on a macro-time scale are thought to be the product of accumulated effects of short-term processes that happen repeatedly in everyday life (Michalowski et al., 2016; Nesselroade, 1991; Ram & Gerstorf, 2009). Thus, investigating such short-term processes can offer important insights on mechanisms connecting daily psychological and physiological responses to overall developmental change. Furthermore, studying daily life processes maximizes ecological validity by taking research out of the lab into individuals' natural environments (Bolger et al., 2009). Prominent relationship models suggest that components of close social networks are interconnected in their dynamic fluctuations moment-to-moment (e.g. Butler, 2011; Feldman, 2007, 2012). Families are thought to be dynamic systems whose members exert reciprocal influence on each other, and respond to challenges and changing environmental conditions in a coordinated and organized way (Cox & Paley, 1997). Thus, individuals are thought to adapt or coordinate their actions, cognitions, and physiology to alterations in actions, cognitions, and physiology of relationship partners (Butler, 2011; Lewis, 2000; Sbarra & Hazan, 2008). Such coordination is hypothesized to result in interdependence of interacting individuals across several channels, including psychological states, behaviours, and psychobiological markers (Butler & Randall, 2013). For example, if one individual encounters a stressor, physiological arousal may spill over from one individual to close others, such as romantic partners (Randall & Bodenmann, 2009; R. Repetti et al., 2009). In this work, I will focus on physiological linkage, because sharing levels of physiological arousal with a significant other may carry particular importance for an individual's health (Timmons et al., 2015).

1.3. Cortisol synchrony

"*At the heart of the universe is a steady, insistent beat: the sound of cycles in sync. It pervades nature at every scale from the nucleus to the cosmos*." (Strogatz, 2003, p. 1)

Investigating dyadic physiological linkage by means of collecting data from couples in the laboratory or in daily life, scientists discovered that data streams from romantic partners tend to covary (Timmons et al., 2015). This phenomenon has been studied under different names including synchrony, convergence, coupling, linkage, co-regulation, reciprocity, resonance, contagion, concordance, attunement, coherence, entrainment, and dyadic covariation. I will focus on the term '***synchrony'*** in the following, because it offers a range of strengths: First, synchrony emphasizes that the underlying health-relevant process involves at least two individuals. Second, it underscores that this process unfolds on a micro time scale. Third, it does not involve any a priori assumptions about its adaptive nature. In other words, unlike concepts such as dyadic harmony, the term synchrony does not preclude that it can sometimes have positive connotations and sometimes negative connotations. Fourth, the co-variation as indicated by the concept of synchrony does not make any assumptions about the underlying causal mechanisms. Co-regulation or reciprocity, for example, imply an active influence of one partner on the other, whereas synchrony also encompasses mutual responses to shared external events. For the purpose of this thesis, I define synchrony as the interdependent association between time-varying states of at least two individuals.

Physiological synchrony in couples has been demonstrated in a number of biological markers of arousal such as cortisol, heart rate, blood pressure, and electrodermal activity (for review see Timmons et al., 2015). Among these markers, cortisol synchrony is expected to be of particular relevance to individuals' health. Cortisol is a marker of hypothalamic pituitary adrenal (HPA) axis activity, one of our major physiological stress response systems, and can be measured in saliva. Studies have demonstrated that particularly contexts that include low control or socio-evaluative threat elicit a marked cortisol response (Dickerson et al., 2008). Salivary cortisol levels tend to rise in a delayed fashion, peaking about 15-20 min after the onset of psychological stress (Kudielka et al., 2009). Whereas an acute cortisol response can be adaptive because it mobilizes energy resources that can help an individual deal with imminent demands, prolonged heightened cortisol secretion can have detrimental effects on physical health (Juster et al., 2010; G. E. Miller et al., 2007). For example, dysregulated cortisol has been associated with increased inflammation, cancer, obesity, and greater functional limitations (Adam et al., 2017; Piazza et al., 2018; Roberge et al., 2007). HPA dysregulation has further been connected with the experience of life events and with psychiatric conditions including depression, posttraumatic stress disorder, and chronic fatigue (Ehlert et al., 2001; Gerritsen et al., 2010).

Cortisol is secreted in a marked pattern throughout the day with high levels in the morning, a pronounced increase about 30-45 min after waking (cortisol awakening response, CAR), and a subsequent decrease with low levels in the evening (R. Miller et al., 2016). In a sample of 19 middle-aged couples, who collected cortisol samples 4 times daily for 4 days at home, Liu et al. (2013) demonstrated that partners show synchronized diurnal cortisol secretion: On a day when one partner had a steeper or less steep cortisol decline than usual, their partner's slope was steeper or less steep, too. Furthermore, studies have found that fluctuations in momentary cortisol levels are linked in romantic partners in daily life (Doerr et al., 2018; Engert et al., 2018; Papp et al., 2013; Saxbe et al., 2015; Saxbe & Repetti, 2010). However, these studies have primarily focused on young to middle-aged samples and less is known about cortisol synchrony in older couples. Yet, physiological linkage with the partner may have particularly strong implications on older adults' health. As compared with younger adults, older adults tend to show impaired HPA axis feedback, which is thought to be the result of accumulated wear and tear on the physiological systems (Juster et al., 2010; McEwen, 1998). The cumulative cost of repeated activation of the HPA axis across the lifespan may contribute to a diminished ability to down-regulate once a stress response is activated, greater basal cortisol levels, and flatter daily cortisol slopes in old age (Nater et al., 2013; Wilkinson et al., 2001). This heightened physiological vulnerability coupled with the increased importance of close social relationships in old age, makes it pivotal to better understand how everyday social processes could contribute to more or less favorable aging profiles.

Figure 1-1 depicts my developmental-contextual model of dyadic synchrony, which guided the current program of research (Pauly et al., under review). Physiological synchrony is expected to be subject to systematic changes across adulthood. Synchrony is thought to be high in young age as early relationship stages tend to be characterized by convergence and a shift in self-concept to seeing oneself as part of the couple (Agnew et al., 1998; C. Anderson et al., 2003). After an initial phase marked by mostly positive interactions, romantic partners have been shown to enter a phase characterized by disillusionment and higher levels of conflict (Huston et al., 2001; Reese-Weber, 2015). During the 'rush-hour of life' in middle adulthood, individuals may focus on their individual occupational goals, pursue different leisure activities, and be confronted with distinct challenges (Infurna et al., in press). Thus, synchrony is expected to be low in middle-aged couples. After a stage of role overload in midlife, relationships are thought to enter a phase of stability, characterized by less conflict, more constructive communication, and more time spent together (Reese-Weber, 2015; Rook & Charles, 2017). Indeed, relationship quality and the amount of positive interactions are thought to increase again once children move out of the house and partners enter retirement (Charles & Carstensen, 2002). Consequently, cortisol synchrony is expected to be high in old age. After a period of relatively high well-being and preserved health, older adults enter a final phase in life, which is typically marked by declining resources. This period, commonly called the 'fourth age' or 'very old age', can be determined by both chronological age and by functional status (Margret M. Baltes, 1998; P. B. Baltes & Smith, 2003). I will focus on the term 'very old age' in this thesis, and define it as a stage of marked cognitive or physical limitations in late life. A decreased physiological flexibility (Charles, 2010) could lead to a diminished capability of biological systems to synchronize with one's partner's physiological states. Furthermore, declining cognitive abilities and audiovisual impairment may undermine an individual's ability to accurately understand their partner's internal states (Hülür et al., 2016; Strawbridge et al., 2007). Thus, broad-based losses of resources are proposed to initiate couple desynchronization in physiology in very old age.

Besides developmental changes, the model proposes that synchrony needs to be considered with respect to features of the immediate everyday environment (proximal context) as well as the overarching structural and societal context, in which the couple is situated (distal context). Synchrony is further expected to be shaped by pertinent individual and dyad characteristics. Finally, effects of everyday couple synchrony are thought to accumulate over time, thereby carrying significant implications for individual and couple functioning, both adaptive and maladaptive. The following sections in this chapter detail how the studies constituting the current thesis tested different predictions derived from the developmental-contextual model of dyadic synchrony, applied to the case of cortisol synchrony in older couples.

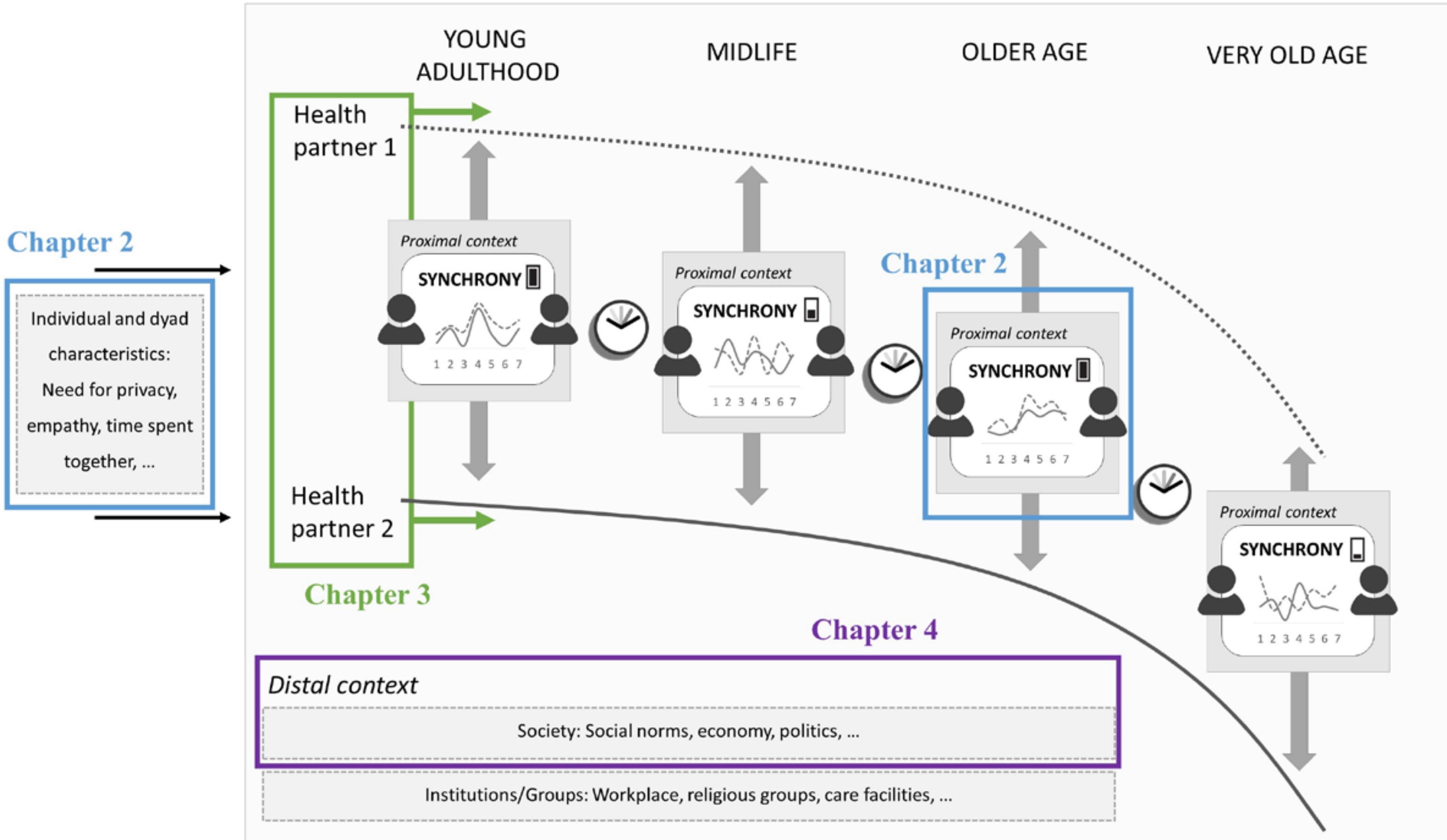

Figure 1-1: A developmental-contextual model of dyadic synchrony.

Note. The figure shows that dynamic fluctuations of everyday physiological states are interconnected in romantic partners (synchrony). Synchrony is expected to be more pronounced among younger and older couples, as compared with middle-aged or very old couples. The extent of synchrony may vary with different proximal and distal contexts. Furthermore, certain characteristics of the person and dyad may shape the propensity for synchrony in couples. Effects of everyday synchrony are thought to accumulate over time, contributing to linked overall health trajectories in couples, for better and for worse.

1.4. Chapter 2: Cortisol synchrony, proximal contexts, and individual differences

As we go through our everyday lives, we move across different proximal contexts, with implications for social dynamics. Two momentary interpersonal contexts that may have particular implications for couple synchrony are *partner presence* and *partner interactions*.

Cortisol synchrony is thought to depend on one partner picking up cues about the internal states of their significant other (Thorson et al., 2018). Even simple tasks such as looking into one another's eyes have been shown to increase brain synchrony, heart rate synchrony, and respiratory synchrony between romantic partners (Helm et al., 2012; Kinreich et al., 2017). In line with this idea, previous daily life research demonstrates that synchrony in cortisol and electro-dermal activity is higher in moments when the partner is present, as compared to moments when the partner is absent (Saxbe & Repetti, 2010; Timmons, Baucom et al., 2017), and on days when partners spend more time together (Butner et al., 2007; Sels et al., 2016). In Chapter 2, I examined whether everyday cortisol synchrony in older couples would be positively associated with partner presence.

Yet, some laboratory studies demonstrate that mere partner presence is not sufficient, but that synchrony only emerges when couples *interact* with one another (Coutinho et al., 2018; Helm et al., 2014; Kinreich et al., 2017; McAssey et al., 2013). Most research on this topic has focused on negative partner interactions (e.g. conflict discussions) and substantial literature has investigated stress spillover between close others (e.g. Timmons, Arbel, & Margolin, 2017). However, being interconnected means sharing the downs *and* ups of daily life, including moments of recovery, companionship, and intimacy (Y. Park & Fritz, 2015; Ryff & Singer, 2000; Stadler et al., 2012). In fact, these positive socio-emotional interactions are thought to carry particular importance for older adults (Carstensen et al., 2003; Zhaoyang et al., 2019). As compared with younger adults, older adults' social goals tend to focus more on quality rather than quantity of social interactions and include a greater emphasis on maintaining emotional closeness with significant others (Carstensen, 1992). Chapter 2 extends previous studies by examining older couples' cortisol synchrony in the context of positive, rather than negative, partner interactions. Thus, this thesis built on previous work by focusing on the types of everyday interactions with a partner that may enhance closeness and well-being. I expected that cortisol synchrony would be more pronounced in moments when older couples report having had a prior positive socio-emotional interaction with their partner.

Besides certain momentary contexts that facilitate physiological synchrony, there may also be inter-individual characteristics that promote cortisol synchrony in romantic partners. One such characteristic that is assumed to play a pivotal role is empathy. In fact, neuroscientists have stressed that being able to recreate another person's internal states in the self lies at the core of the empathic process (Singer & Lamm, 2009; Vignemont & Singer, 2006). For example, researchers have demonstrated that empathy with others' pain goes along with activation of brain areas that are involved in processing own pain (Lamm et al., 2011). Most studies on the biological substrate of empathy have focused on affective states, but there is preliminary evidence that empathy can also elicit a change in physiological states (Engert et al., 2014; Manini et al., 2013). An individual that is able to mirror or simulate their partner's affective and mental states by sharing these states, may show greater linkage in physiological arousal to their significant other. In other words, the same skill that enables effective support provision may also make romantic partners more susceptible to each other's stress (Devoldre et al., 2010). Providing support to this notion, prior studies have linked greater self-rated empathy to greater coupling of respiratory rate and heartrate (Goldstein et al., 2017) and greater synchrony in electrodermal activity (Chatel-Goldman et al., 2014; Coutinho et al., 2018) in young to middle-aged couples. Similarly, a study measuring physiological synchrony as a composite measure of linkage in heart rate, skin conductance level, general somatic activity, pulse transmission time, and finger pulse amplitude found that partners who displayed greater synchrony more accurately judged their partner's negative affect, as compared to individuals who were less 'in sync' with their partner (Levenson & Ruef, 1992). These studies have primarily been conducted with young to middle-aged samples and in the laboratory. I extended these findings in Chapter 2 by investigating whether greater self-rated empathy was linked with greater everyday cortisol synchrony in older couples.

To summarize, Chapter 2 focused on two facets of the developmental-contextual model of dyadic synchrony: It related cortisol synchrony in older couples to two different proximal context indicators (partner presence, positive socio-emotional partner interactions) and to a pertinent individual difference characteristic (self-rated empathy). In light of the recent debate regarding concerns about the lack of reproducibility of scientific research across different fields, and in Psychology in particular (e.g. Open Science Collaboration, 2012, 2015), I tested my research questions in two independently collected data sets using parallel statistical protocols, aiming for constructive replication. Chapter 2 zoomed into older couples' everyday life. Yet, in order to better understand how everyday cortisol synchrony might affect older adults' health and well-being in the long term, it is necessary to go beyond the daily context. This was the aim of Chapter 3.

1.5. Chapter 3: Cortisol synchrony and long-term outcomes

Researchers have emphasized that micro-processes that recur on a daily basis can ultimately accumulate to put individuals on more or less favorable aging trajectories (Almeida et al., 2011; R. L. Repetti et al., 2011). Chapter 3 aimed to link daily cortisol synchrony with longer-term changes in relationship functioning and health. Interdependence theory (Kelley et al., 1983; Kelley & Thibaut, 1978) posits that partners' functioning is linked and that this interdependence may have positive as well as negative ramifications for both partners. Building on this idea, it was expected that cortisol synchrony may be a double-edged sword with both positive and negative connotations.

Synchrony may relate to positive relationship functioning. Researchers take the fact that individuals unconsciously and automatically synchronize movements with others around them as evidence for synchrony's important role in interpersonal processes, acting as a social glue (Lakin et al., 2003). Specifically, experimental research has demonstrated that synchrony enhances understanding and compassion towards the partner (Valdesolo & Desteno, 2011). This is supported by neuro-imaging research showing that synchrony activates brain areas associated with social cognition, self-other expansion, and behavioural observation (Cacioppo et al., 2014). Studies manipulating synchrony in context of a collaborative task point out that synchrony may also enhance effective cooperation between partners, allowing partners to coordinate their behaviour with each other (Behrens et al., 2019; Miles et al., 2017; Wiltermuth & Heath, 2009). Finally, synchrony may be linked with perceptions of greater unity with the partner, which may foster relationship commitment (Branand et al., 2019; Lakens & Stel, 2011; Paladino et al., 2010).

Several studies have associated positive relationship functioning with lower cortisol levels. For example, daily cortisol output has been shown to be reduced on days when middle-aged partners spend more time exchanging intimacy (Ditzen et al., 2008). Furthermore, greater observed social reciprocity between partners during laboratory tasks involving giving support and talking about a shared positive experience, greater focused attention on this task, and greater self-reported relationship commitment were associated with decreased total daily cortisol secretion in young romantic couples (Weisman et al., 2015). Yet, the Physiology of Romantic Pair Bond Initiation and Maintenance model (Mercado & Hibel, 2017) suggests that activation of the HPA and autonomic nervous system in a non-stress context facilitates approach behaviour towards the partner, attentiveness to cues from the partner, and emotional connectedness. Indeed, thinking deeply about one's romantic partner and one's relationship has been linked with concurrent increases in cortisol, relative to thinking about a friendship (Loving et al., 2009). Similarly, the conceptual model on bio-behavioural synchrony (Feldman, 2012) highlights the importance of similarity in activated physiological responses patterns between attachment partners for behavioural coordination and the formation of affiliative bonds. Thus, be it joint increases or joint decreases in cortisol, temporal coordination of cortisol fluctuations in romantic partners may be associated with more positive relationship indicators.

However, having more permeable boundaries and being more susceptible to physiological fluctuations of one's significant other may also have negative health implications (Kiecolt-Glaser & Wilson, 2017). Being in tune with one's partner may be adaptive and important for facilitating closeness and relationship functioning (Mercado & Hibel, 2017). Yet, such close linkage may entail sharing of positive as well as negative events and psychological states. Consequently, greater synchrony could be accompanied by physiological stress responses spilling over from one partner to the other more frequently (Kiecolt-Glaser & Wilson, 2017). If this happens repeatedly in an everyday context, partners may over time build up allostatic load as the cumulative cost of repeated cortisol responses (McEwen, 1998; McEwen & Seeman, 1999). The allostatic load framework posits that repeated and prolonged activation of the stress system causes physiological wear and tear with important ramifications for the immune system, cardiovascular functioning, and metabolic processes (Juster et al., 2010; McEwen & Stellar. E., 1993; Seeman et al., 1997). If, in the case of greater physiological linkage, individuals experience a greater amount of cortisol elevations, they may thus be at increased risk for stress-related disorders (R. Repetti et al., 2009; Timmons et al., 2015). Altered blood lipid levels may be one biological mechanism linking increased HPA axis activity to cardiovascular disease, specifically (Rosmond & Björntorp, 2000). Elevated cortisol secretion has been associated with greater levels of maladaptive lipids, and with increased coronary calcification and higher plaque scores (Dekker et al., 2008; Hajat et al., 2013; Hamer et al., 2010; Matthews et al., 2006; Rosmond et al., 1998).

In Chapter 3, I made use of the longitudinal component of one of the studies presented in Chapter 2 (LL project), which included yearly assessments of relationship satisfaction and assays of blood lipid levels over a 3-year period. Specifically, I expected that greater cortisol synchrony would be associated with greater levels of relationship satisfaction, and greater increases in relationship satisfaction 1 and 2 years later. However, at the same time, being linked to one’s partner may also take a toll on an individual’s physiological systems in the long run, as indicated by worse lipid profiles. Thus, I expected that higher cortisol synchrony would also be associated with more negative lipid profiles, and a worsening of lipid levels 1 and 2 years later.

1.6. Chapter 4: Linking the micro with the macro

This thesis started out by emphasizing that individuals do not operate in a social vacuum, but that they are strongly linked to close others around them. Similarly, social units such as couples exist in a broader societal and cultural context (Bronfenbrenner, 1981). Indeed, researchers have pointed out that we can only fully understand the relationship between social relationships and health if we extend our perspective from studying micro-level psychosocial processes to also consider ‘upstream’ or ‘distal’ factors that influence the nature and structure of smaller social units (Berkman et al., 2000). Thus, Chapter 4 built on the micro-level perspective of Chapters 2 and 3, to test another prediction derived from the developmental-contextual model of dyadic synchrony: that features of the social architecture couples live in are intertwined with older couples’ everyday cortisol synchrony (Pauly et al., under review).

One feature of the distal, or macro, context that is thought to shape the structure of our social relationships is political ideology. Politics are tied to prevalent norms and values, and can directly influence couple dynamics through laws and social policy (Jost et al., 2009). Thus, political ideology may create a certain scaffolding, in which relationships are formed and experienced in daily life. Among different organizing schemes for the political spectrum, the Left-Right (L-R) continuum counts among the most parsimonious and most widely-used indices (Jost, 2006). The L-R scale closely resembles the liberal-conservative scale, which is more common in Anglo-American countries. There is a distinct lack of research examining daily couple dynamics within their broader socio-political context. Yet, multiple reasons support the notion that right- and left-oriented ideology are linked with interpersonal processes. For example, right-oriented ideology promotes traditionalism, family values, and social responsibility for in-group members (Graham et al., 2012; Jost et al., 2009; Thorisdottir et al., 2007). On the other hand, left-oriented ideology has been associated with greater compassion for others, more display of open interpersonal social behaviours, and higher endorsement of reciprocity (Carney et al., 2008; Graham et al., 2009; Graham et al., 2012).

In Chapter 4, I utilized a national data set of German couples residing in different German federal states to examine whether cortisol synchrony in older couples may differ based on how far left or right the respective federal state of residence is placed on the L-R ideological spectrum. I did not make any a-priori assumptions about the direction of the association in light of the lack of empirical research on this topic and as there is theoretical support for cortisol synchrony being more pronounced in a more right-oriented or a more left-oriented context. In the statistical analyses, I combined information about the L-R ideological context with individuals' self-reported political views. Thus, I was able to investigate the unique contextual association with couple synchrony, controlling for individuals' own political L-R orientation.

1.7. Summary of research objectives

The proposed research program aimed to better understand the phenomenon of linked cortisol fluctuations in older couples' everyday life, by examining its proximal and distal correlates, its relation to individual differences, and its long-term implications. The following chapters present three studies, which take different perspectives on cortisol synchrony, based on my developmental-contextual model of dyadic synchrony (*Figure 1-1*). Study 1 (Chapter 2) investigated the role of proximal correlates (partner presence, positive socio-emotional partner interactions) and individual differences in empathy for cortisol synchrony. The key research aim was to identify everyday contexts and interpersonal characteristics linked to more pronounced cortisol synchrony in older couples. Study 2 (Chapter 3) contextualized this research by examining broader adaptive and maladaptive implications of synchrony for longer-term trajectories of relationship functioning and health. Specifically, it related cortisol synchrony to initial levels of and changes over time in relationship satisfaction and blood lipid levels as an indicator of cardiovascular risk. Study 3 (Chapter 4) adopted a macro perspective, taking a step back to consider broader societal correlates of cortisol synchrony. In particular, it tied cortisol synchrony to older couples' political ideological context (L-R political spectrum).

Three participant samples were included in this research: 1) 170 older adults (85 couples) from Vancouver, Canada, part of the Linked Lives (LL) project; 2) 154 older adults (77 couples) from Berlin, Germany, part of the Berlin Couple Dynamics (BCD) project; and 3) 320 older adults (160 couples) from different geographical locations across Germany, part of the Everyday Life of Older Couples (ELOC) project; for a total of 644 participants. All three data sets included daily life assessments of psychobiosocial phenomena. Collecting repeated measures in couples' everyday life offers the unique advantage of observing social processes, and their psychological and physiological correlates, as they unfold naturally (R. L. Repetti et al., 2015). This comes with the benefit of reducing recall bias and maximizing ecological validity (Hoppmann & Riediger, 2009; Laurenceau & Bolger, 2005; Röcke et al., 2011). Furthermore, researchers have pointed to the concern that observations of couple interactions in the laboratory, in particular, may be vulnerable to social desirability (Laurenceau & Bolger, 2005). The LL, BCD, and ELOC projects utilized similar daily assessment protocols: Salivary cortisol was collected multiple times a day (5-7 times) alongside brief electronic questionnaires answered on a mobile device for a period of 7 days.

I selected these data sets for my thesis because each project features a unique component that made it possible to address core questions from my theoretical research program. First, the LL and BCD projects contain similar electronic information concurrent to saliva samples, allowing the opportunity for constructive replication of my predictions with regards to proximal contexts of couple synchrony (Chapter 2). Second, the LL project supplemented the daily life protocol with longitudinal assessments of individual and couple functioning over a 3-year period, allowing the investigation of long-term correlates of couple synchrony (Chapter 3). Third, because older couples in the ELOC project resided in different geographical locations across

Germany, this data set came with the unique opportunity to examine socio-political correlates of cortisol synchrony (Chapter 4). The respective number of observations at the within-person level (35 to 49 cortisol assessments) and at the couple level (77 to 160 couples) conform to sample size recommendations for adequate power in multilevel study designs (Maas & Hox, 2005; Scherbaum & Ferreter, 2009).

Chapter 2: Links between partner presence, partner interactions, empathy, and everyday cortisol synchrony

A version of this chapter is accepted at Psychosomatic Medicine, titled ‘Cortisol synchrony in older couples: Daily socio-emotional correlates and interpersonal differences’.

2.1. Introduction

There is ample support for a strong connection between social relationships and health (T. W. Smith, 2019). Yet, less is known about specific underlying biological mechanisms. Everyday assessments of social interactions and stress-related physiological markers (such as salivary cortisol) using repeated daily-life assessments have the potential to shed light on everyday processes that may accumulate over time to shape individual health trajectories for better or worse (T. W. Smith, 2019). This design offers unique insights into dynamic social exchange processes and it also maximizes ecological validity (Laurenceau & Bolger, 2005). In line with this idea, a recent study demonstrated that naturalistically measured cardiovascular reactivity was a better predictor of relationship and individual functioning in couples than reactivity in a laboratory conflict task (Baucom et al., 2018). The current manuscript builds on this research by examining cortisol co-variation among older romantic partners in their everyday life, and by linking such synchrony with momentary self-reports of time-varying social contexts and interactions (partner presence, positive socio-emotional partner interactions) as well as with inter-individual differences in empathy. It investigated these questions utilizing data of two older adult couple studies.

2.1.1. Social relationships, health, and aging

The structure and quality of social networks change across the adult lifespan (Carstensen et al., 2003). Age-normative declines in resources and the onset of health problems such as chronic disease result in an increased reliance on other people such as romantic partners for support (Hoppmann & Gerstorf, 2016). Furthermore, with perceptions of decreasing time left in life, older adults prioritize maintaining close emotionally meaningful social relationships, they interact more with close social partners such as their spouse, and derive more satisfaction from these interactions (Carstensen et al., 2003). Speaking to the importance of spousal interrelations in older adults, developmental trajectories in health and well-being are closely linked in older couples (Hoppmann & Gerstorf, 2016). Such health concordance may partly be driven by individuals entering relationships with partners with similar characteristics, but also by shared environments and everyday interactions (Ask et al., 2012). What remains to be determined is how social relationships are connected to health in an everyday environment.

2.1.2. Cortisol synchrony

Physiological processes have been shown to be related in the laboratory and in daily life among romantic partners. *Physiological synchrony*, defined as the interdependent association of dynamic fluctuations in physiological states between two individuals over time, has been demonstrated in a number of biological markers of arousal including cortisol, heart rate, blood pressure, and electrodermal activity (for review, see Timmons et al., 2015).

Cortisol is a marker of hypothalamic-pituitary-adrenal (HPA) axis activity, one of the main physiological stress response systems. The HPA axis is sensitive to positive and negative social contexts, including social support and social evaluative threat (Dickerson & Kemeny, 2004; Kirschbaum et al., 1995). Prolonged elevated cortisol has been associated with a number of mental and physical health risks, including depression, obesity, and increased inflammation (Adam et al., 2017). Due to this close connection with chronic disease risk and its sensitivity to social input, cortisol seems to be a promising marker to study physiological linkage in older couples. Examining cortisol synchrony, over and above individual cortisol levels, may allow to shed light on co-regulatory patterns influencing health in couples. Prior studies have demonstrated that patterns of daily cortisol secretion as well as fluctuations in momentary cortisol levels are linked in romantic partners in daily life (Liu et al., 2013; Papp et al., 2013; Saxbe & Repetti, 2010). However, these studies have primarily focused on young to middle-aged samples and less is known about cortisol synchrony in older couples. Physiological synchrony with a partner may have particularly strong implications for older adults' health. Older adults tend to show age-related HPA axis feedback impairment, contributing to a diminished ability to down-regulate stress responses, greater basal cortisol levels, and flatter daily cortisol slopes (Charles, 2010; Nater et al., 2013). This physiological vulnerability coupled with the increased importance of close social relationships in old age makes it pivotal to better understand the connection between everyday social contexts and fluctuating cortisol levels.

2.1.3. Cortisol synchrony and time-varying everyday social contexts

Physical proximity may allow physiological processes to 'synchronize' in romantic partners. In line with this idea, previous daily-life research demonstrates that synchrony in cortisol and electrodermal activity is higher during moments of partner presence as compared with moments when the partner is absent (Saxbe & Repetti, 2010; Timmons, Baucom et al., 2017) and on days when partners spend more time together (Butner et al., 2007; Sels et al., 2016). Furthermore, laboratory studies demonstrate that synchrony changes when couples interact with one another (Coutinho et al., 2018; Helm et al., 2014). Most research on this topic has focused on negative partner interactions, with a primary emphasis on conflicts. Yet, being interconnected means sharing the downs *and* ups of daily life, including moments of disclosure and intimacy (Ditzen et al., 2008; Slatcher et al., 2010). In fact, these positive socio-emotional interactions may carry particular importance for older adults daily physical health (Carstensen et al., 2003; Zhaoyang et al., 2019). Zhaoyang et al. (2019) demonstrated that while frequency of social interactions was related to daily physical symptoms in younger adults, it was the positivity of these interactions—not their quantity—that mattered for older adults' physical symptoms. Prior studies with younger samples conducted in the laboratory have linked positive partner interactions such as talking about positive aspects of the relationship or about a topic partners agree on with greater physiological synchrony as compared with a non-social baseline (sitting next to each other without talking or completing an attention task together; Coutinho et al., 2018; Helm et al., 2014). Thus, cortisol synchrony likely emerges in negative as well as positive social contexts.

In line with the idea that positive socio-emotional partner interactions may help down-regulate sympathetic arousal in both partners, daily life studies have linked disclosure and intimate behaviours to lower cortisol levels (Ditzen et al., 2008; Slatcher et al., 2010). Feeling that the partner understands, appreciates and values, and cares about oneself has been linked with healthier cortisol trajectories 10 years later (higher wakeup values, steeper slopes; Slatcher et al., 2015). Consequently, cortisol synchrony was expected to be greater in moments when the partner is present as compared with moments when the partner is absent, and in moments when partners report having had a prior positive socio-emotional interaction with each other. Specifically, we defined positive socio-emotional partner interactions as seeking support/closeness or feeling understood/valued by the partner.

2.1.4. Cortisol synchrony and interindividual differences in empathy

Besides time-varying everyday social contexts that facilitate physiological synchrony, there may also be interindividual differences that promote cortisol synchrony in romantic partners, such as empathy. In fact, the ability to recreate another person's internal states lies at the core of the empathic process (Singer & Lamm, 2009). Empathy involves both cognitive (i.e., making inferences about other's internal states) and emotional components (i.e., affective states that are elicited by or match other's internal states; Singer & Lamm, 2009).

An individual who is able to mirror or simulate their partner's internal states by recognizing them may show greater linkage in physiological arousal to their significant other. Supportingly, prior studies have linked greater self-rated empathy to greater synchrony of cortisol (Engert et al., 2014), respiratory rate and heartrate (Goldstein et al., 2017), and electrodermal activity (Chatel-Goldman et al., 2014; Coutinho et al., 2018) in young to middle-aged couples. Given the importance of empathy for positive relationship functioning and considering the potential age-related decline in cognitive empathy due to cognitive resource loss (Kunzmann & Wrosch, 2017), the current study extended these findings by investigating whether greater self-rated empathy is related to greater cortisol synchrony in older couples' daily life. The role of both self-reported cognitive (as measured via perspective-taking) and emotional (as measured via emotional concern; Paulus, 2009) empathy for cortisol synchrony was considered.

2.1.5. The current study

The aim of this study was to quantify cortisol synchrony in older couples, to identify its everyday social correlates, and to link cortisol synchrony to trait-level empathy. We used a coordinated analysis approach to respond to recent calls for constructive replication, i.e., to corroborate results across samples, designs, and measures so as to provide a more comprehensive test of hypotheses (Hofer & Piccinin, 2009). We expected that cortisol synchrony would be more pronounced in moments when the partner is physically present as compared with moments when the partner is physically absent. We further hypothesized that cortisol synchrony would be higher when partners report having had a prior positive socio-emotional interaction with each other. Finally, we anticipated that individuals with greater self-reported empathy exhibit more pronounced cortisol synchrony with their significant other. Several covariates on the momentary and individual level that have been linked with HPA axis functioning were considered in the analysis, including: time since waking, prior caffeine/alcohol/food intake, showering or brushing teeth, and physical activity (momentary level); and sex and age (person level; Hoppmann et al., 2016).

2.2. Methods

2.2.1. Participants

This manuscript presents secondary analyses of two older adult couple studies (LL project: Pauly, Michalowski, Nater et al., 2019; BCD project: Brinberg et al., 2017; Hülür et al., 2016). Relevant methodological details are presented in the following and in Appendix A. Data from the LL project include 85 heterosexual couples (*M* age = 71.2 years, *SD* = 6.1, range: 60-87; 58% White; 37% at least some college education) living in Metro Vancouver, Canada from a project on health dynamics in older spouses (March 2013 to April 2017). The BCD sample is comprised of 77 couples aged 66-85 years (76 heterosexual, 1 same-sex; *M* age = 74.4 years, *SD* = 3.4; 38% at least some college education) from a study on older couples' everyday life in Berlin, Germany (February 2012 to January 2014). Participants in both studies reported good self-rated health (LL project: *M* = 3.3 out of 5, 'poor' to 'excellent'; *SD* = 1.0; BCD project: *M* = 3.6/5; *SD* = 0.7, 'very poor' to 'very good') and high relationship satisfaction (Study 1: *M* = 4.3/5; *SD* = 0.9; Study 2: *M* = 6.1/7; *SD* = 0.9). Recruitment strategies included existing participant pools and advertisements in newspapers, online, and community organizations (LL project) and newspaper announcements (BCD project). Informed consent was obtained from all participants and ethical approval was granted by the University of British Columbia Research Ethics Board (for the LL project and secondary data analysis of the BCD project) and by the Humboldt University Berlin Ethics Board (BCD project). Participants received $100 CAD in the LL project and 100 € in the BCD project.

2.2.2. Procedure

In both projects, participants took part in an in-person interview session and a subsequent 7-day period of tablet-based daily-life assessments using a senior-friendly survey app (iDialogpad; G. Mutz, Cologne, Germany). Concurrent to answering the daily questionnaires (LL project: waking, 30 min post waking, 11am, 4pm, and 9pm; Study 2: waking, 30 min post waking, 10am, 1pm, 4pm, 7pm, 9:30pm), participants collected saliva samples using Salivettes (Sarstedt, Germany). At the end of the 7 days, couples took part in a final in-person session to return study materials, provide study feedback, and complete additional measures. Participants considered the study period to be typical for their everyday lives (LL project: M = 3.7, SD = 1.1; BCD project: M = 3.6, SD = 1.1; 1 = 'not at all' to 5 = 'very much'). In the BCD project only, participants completed questionnaire packages during the study period and approximately 1 year post participation. Relevant individual difference measures are from the in-person interviews and the take-home packages.

2.2.3. Measures

2.2.3.1. Partner presence

In the daily assessments at waking and throughout the day, partner presence was recorded on each occasion (0 = not with partner, 1 = with partner). This information was not available for the second daily assessment point. Scores were aggregated over the study period to estimate average time spent together (LL project: *M* = 79%, *SD* = 19%; BCD project: *M* = 76%, *SD* = 23%).

2.2.3.2. Positive socio-emotional interactions

In both studies, participants were asked questions about partner interactions.[1] In the LL project, participants were asked with who they had their "most important social interaction since the last questionnaire". They indicated whether this interaction involved "*feeling understood and appreciated*". In the BCD project, participants answered the question: "Since the last questionnaire, did you *recruit the help of or seek closeness to your partner*?" Participants reported prior positive socio-emotional partner interactions in 11.1% (*SD* = 31.4%; LL project) and 36.1% (*SD* = 24.2%; BCD project) of daily assessments. This information was not available for the two morning assessments.

2.2.3.3. Salivary cortisol

At each momentary assessment point, participants were asked to take a synthetic stick out of a pre-labelled tube (Salivettes; Sarstedt, Germany) indicating time point and day of study, place it in their mouth, and remove it after finishing the assessment (or when the synthetic stick was saturated with saliva). To capture cortisol's diurnal rhythm (Kudielka et al., 2012), participants collected five (LL project; waking, plus 30 min, 11 AM, 4 PM, 9 PM) and seven (BCD project; waking, plus 30 min, 10 AM, 1 PM, 4 PM, 7 PM, 9:30 PM) samples spaced approximately evenly across the day. Participants stored saliva samples in their personal fridge or freezer until they were returned to the lab for storage at -31°C. Cortisol assays were conducted

[1] Studies also asked for negative interactions, but they were rarely reported (at 3.7% of all assessments in Study 1, 6.2% in Study 2). In Study 2, cortisol synchrony was lower when partners reported having had a negative interaction since the last beep (*b* = -0.06, *SE* = .03, *p* = .04). However, we are hesitant to interpret these findings due to the low incidence rate.

by Clemens Kirschbaum's laboratory in Dresden, Germany. Due to skewness of the distribution, cortisol values were log-transformed (LL project: $M = 0.99$ $\log_{10}$nmol/L, $SD = 0.40$; BCD project: $M = 0.92$ $\log_{10}$nmol/L, $SD = 0.40$). Compliance with the collection protocol was high; participants provided a mean of 32 (91%) out of 35 and 48 (98%) out of 49 samples in the LL and BCD projects.

2.2.3.4. Empathy

Trait-empathy was assessed in the BCD project using the 16-item German version of the Interpersonal Reactivity Index (IRI; M. H. Davis, 1980; Paulus, 2009). The IRI is a widely used multi-dimensional measure designed to assess individual differences in dispositional empathy and has demonstrated good psychometric properties across the adult lifespan (Gilet et al., 2013; Keaton, 2017; Paulus, 2009). Specifically, two subscales were used that contain 4 items each to measure cognitive empathy (subscale perspective-taking; $M = 3.56$, $SD = 0.64$, $\alpha = 0.65$) and emotional empathy (subscale empathic concern; $M = 3.64$, $SD = 0.63$, $\alpha = 0.57$) on a 5-point Likert scale. An empathy measure was not available in the LL project.

2.2.3.5. Covariates

In the 7-day daily life assessments, participants reported whether they had smoked; consumed caffeine, alcohol, or food; engaged in physical activity; or taken medication/drugs in the hour prior to the saliva collection. The two morning questionnaires additionally asked whether participants had taken a cold shower or brushed their teeth, and whether they had gone back to sleep. For model parsimony, only significant variables were included as covariates.[2]

[2] This approach was chosen because models did not converge when including all momentary covariates and random slopes for cortisol synchrony. Models omitting random slopes but retaining all momentary covariates and additionally controlling for body mass index, retirement status, and education replicate results from reported models.

Models further include time since waking to account for the diurnal rhythm of cortisol and adjust for pertinent individual covariates (sex, age).

2.2.4. Statistical analyses

The two separately collected data sets were analyzed using parallel statistical protocols, implementing a coordinated analysis approach for constructive replication (Hofer & Piccinin, 2009). To account for the nested data structure, multilevel models were computed using the R lme4 package (Bates et al., 2015). Cortisol deviation scores were calculated by subtracting the person and measurement point specific mean from absolute cortisol levels. Thus, deviation scores depicted whether cortisol levels were higher or lower than usual for that individual for that time of day. To model cortisol synchrony, an individual's cortisol level at a certain measurement point was estimated as a function of their partner's cortisol deviation score. Next, couples' cortisol synchrony estimates (random slopes) were extracted from multilevel models and compared with synchrony estimates of randomly paired partners. Then, interactions were included at the momentary and person level to test predictions about associations between time-varying and individual difference variables with cortisol synchrony. A step-wise approach was chosen because the number of available observations differed for each model due to differences in daily questionnaires and missing data.

2.3. Results

Table 2.1 displays descriptive statistics and intercorrelations of central study variables. In the LL project, age was correlated with time spent with the partner ($r = .31$, $p < .001$). Perspective-taking and empathic concern were positively correlated in the BCD project ($r = .25$, $p = .005$). Importantly, cortisol fluctuations co-varied among partners across studies (i.e. cortisol synchrony, see *Table 2.2* and *Table 2.3* Model A; LL project: $b = 0.04$, $SE = 0.01$, $p < .001$; BCD project: $b = 0.03$, $SE = 0.01$, $p = .001$). Thus, if one partner displayed cortisol levels that were higher than usual for them at that time of day, their partner displayed elevated cortisol levels, too (*Figure 2-1* exemplifies low and high synchrony). A comparison of couples' cortisol synchrony indices with indices of random partner pairings showed that cortisol fluctuations were not significantly linked in random pairs (LL project random synchrony coefficient: $b = 0.006$, $SE = 0.021$, $p = .788$, BCD project random synchrony coefficient: $b = 0.007$, $SE = 0.008$, $p = .379$). A repeated measures t-test confirmed that cortisol synchrony was significantly higher in romantic couples than in random partners (LL project: $t = 5.82$, $df = 84$, $p < .001$; BCD project: $t = 4.18$, $df = 76$, $p < .001$).

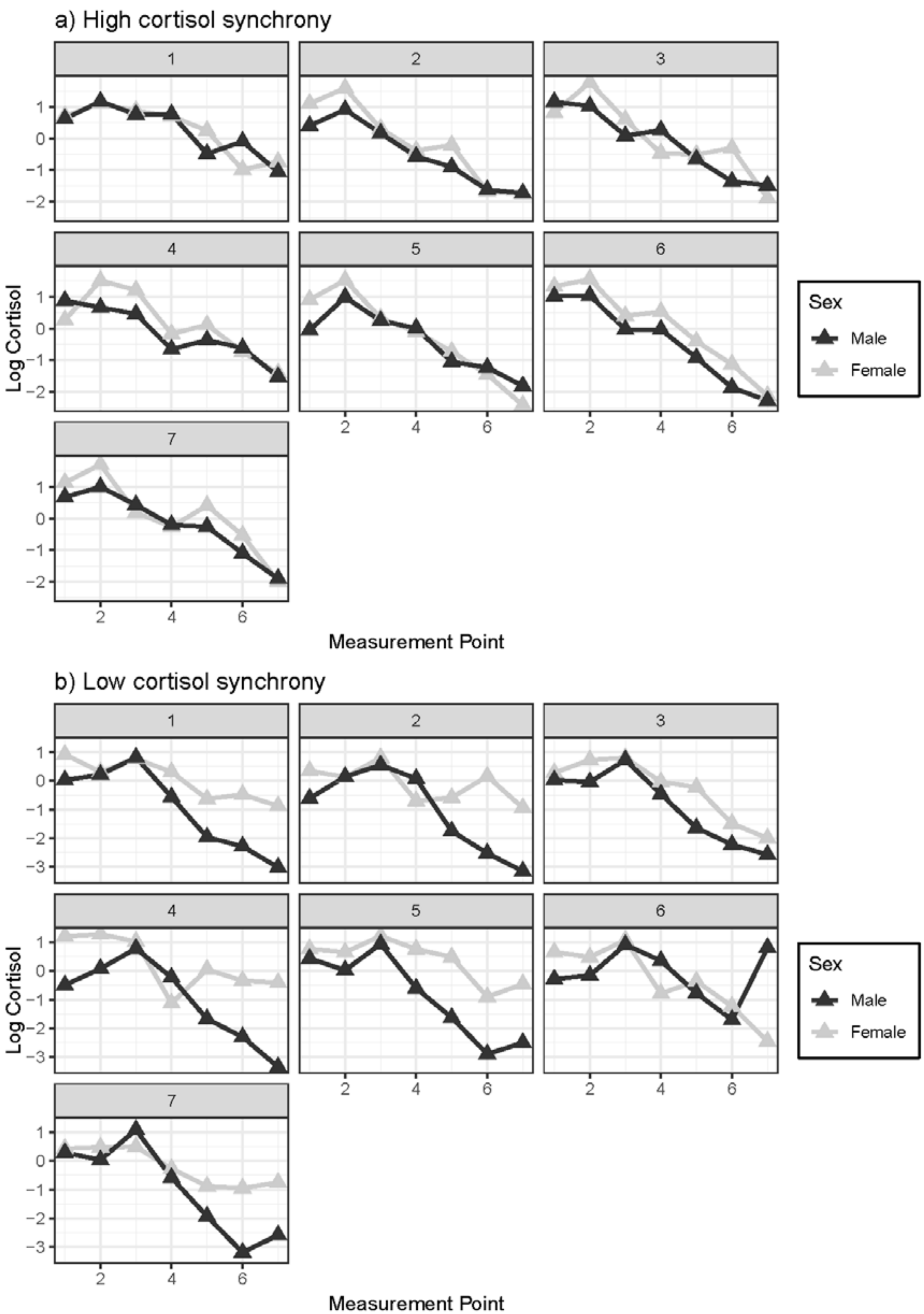

Figure 2-1: Examples of partners' daily cortisol trajectories over the study period (day 1 through 7) for two couples from the BCD project with high synchrony (a) and low synchrony (b)

Table 2.1: Means, standard deviations, and intercorrelations of central study variables, LL project (N = 85 couples) and BCD project (N = 77 couples)

Variable	Mean (*SD*) LL project/ BCD project	2	3	4	5	6	7
1. Age	71.18 (*6.06*) / 74.36 (*3.38*)	.11/.06	–.10/–.07	.31**/.04	–.04/.05	na/–.15	na/–.10
2. Log-Cortisol	0.99 (*0.40*) / 0.92 (*0.40*)		–.00/.05	.00/–.07	–.02/.01	na/.16	na/–.06
3. Cortisol synchrony	0.04 (*0.03*) / 0.03 (*0.05*)			–.03/–.08	.04/–.04	na/.16	na/.05
4. Person average time spent together	0.79 (*0.19*) / 0.76 (*0.23*)				.04/.09	na/.01	na/–.14
5. Person average positive socio-emotional interactions	0.11 (*0.15*) / 0.36 (*0.24*)					na/.04	na/.08
6. Perspective-taking	na / 3.56 (*0.64*)						na/.25**
7. Empathic concern	na / 3.64 (*0.63*)						

Note. SD = standard deviation. Na = not applicable. * $p < .05$. ** $p < 0.01$.

Table 2.2: Fixed effects estimates for multilevel models predicting cortisol levels (log_{10}nmol/L) in the LL project using restricted maximum likelihood estimation (N = 85 couples)

	Model A	Model B	Model C
Variable	B (SE)	B (SE)	B (SE)
Intercept	**0.86*** (0.04)**	**0.73*** (0.04)**	**0.32*** (0.06)**
Time since waking	**–0.19*** (0.01)**	**–0.17*** (0.01)**	**–0.08*** (0.01)**
Time since waking squared	**0.00*** (0.00)**	**0.00*** (0.00)**	**0.00** (0.00)**
Partner cortisol deviation	**0.04*** (0.01)**	–0.01 (0.02)	**0.03* (0.01)**
Average time spent together		–0.08 (0.16)	
Partner presence		–0.01 (0.02)	
Partner cortisol deviation x partner presence		**0.06** (0.02)**	
Person mean positive socio-emotional interaction			–0.07 (0.19)
Positive socio-emotional interaction			–0.02 (0.04)
Partner cortisol deviation x positive socio-emotional interaction			**0.09** (0.03)**

Note. SE = standard error. Models control for age and sex on the person level and for prior exercise, intake of alcohol, caffeine, or food, and falling asleep on the momentary level. The outcome (log_{10} Cortisol levels) and partner cortisol deviation were z-standardized. Bold font denotes significant regression coefficients. Models A, B, and C include 5045, 4059, and 3004 cortisol values of 170 participants, respectively. * *p* < .05. ** *p* < .01. *** *p* < .001.

Table 2.3: Fixed effects estimates for multilevel models predicting cortisol levels (log$_{10}$nmol/L) in the BCD project using restricted maximum likelihood estimation (N = 64-77 couples)

Variable	Model A B (SE)	Model B B (SE)	Model C B (SE)	Model D B (SE)
Intercept	**1.10*** (0.04)**	**0.92*** (0.04)**	**0.72*** (0.05)**	**1.11*** (0.04)**
Time since waking	**–0.19*** (0.00)**	**–0.15*** (0.00)**	**–0.10*** (0.01)**	**–0.19*** (0.00)**
Time since waking squared	**0.00*** (0.00)**	**0.00* (0.00)**	**0.00*** (0.00)**	**0.00*** (0.00)**
Partner cortisol deviation	**0.03** (0.01)**	0.02 (0.02)	**0.03* (0.01)**	**0.03** (0.01)**
Average time spent together		0.00 (0.12)		
Partner presence		**–0.04* (0.02)**		
Partner cortisol deviation x partner presence		0.02 (0.02)		
Person mean positive socio-emotional interaction			0.20† (0.12)	
Positive socio-emotional interaction			**–0.04* (0.02)**	
Partner cortisol deviation x positive socio-emotional interaction			**0.04** (0.02)**	
Perspective-taking				**0.09* (0.04)**
Partner cortisol deviation x perspective-taking				0.02† (0.01)

Note. SE = standard error. Models control for age and sex on the person level and for prior exercise, alcohol intake, showering or brushing teeth, and falling asleep on the momentary level. The outcome ($\log_{10}$ Cortisol levels) and partner cortisol deviation were z-standardized. Bold font denotes significant regression coefficients. Models A, B, and C include 7246, 6229, and 5188 cortisol values of 154 participants, respectively. Empathy data (Model D) was available for $n = 128$ participants. † $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

2.3.1. Cortisol synchrony and time-varying everyday social contexts

We hypothesized that cortisol synchrony would be higher in moments when the partner is present and in moments when participants had a recent positive socio-emotional interaction with their partner as compared with moments when the partner was absent or without a prior positive socio-emotional interaction. As can be seen in Models B presented in *Tables 2.2* and *2.3*, partner presence and cortisol synchrony were positively associated in the LL sample (b = 0.06, SE = 0.02, p = .003) but not in the BCD sample (b = 0.02, SE = 0.02, p = .187). Furthermore, cortisol synchrony was not related with couples' overall time spent together. However, there was a significant main effect of partner presence on cortisol levels in the BCD project (b = –0.04, SE = 0.02, p = .040), indicating that older adults, on average, had lower cortisol levels in moments when their partner was present, as compared with moments when their partner was absent.

In both studies, prior positive socio-emotional interactions were linked with more pronounced cortisol synchrony (see *Tables 2.2* and *2.3* Model C and *Figure 2-2*; LL project: b = 0.09, SE = 0.03, p = .005; BCD project: b = 0.04, SE = 0.02, p = .005). Follow-up analyses indicated that these associations were moderated by age in such a way that associations between socio-emotional interactions and cortisol synchrony were less strong in older participants (LL project: b = –0.01, SE = 0.01, p = .027; BCD project: b = –0.01, SE = 0.00, p = .003). Additionally, in the BCD project, cortisol levels were lower on average in moments when participants reported prior positive socio-emotional partner interactions (b = –0.04, SE = 0.02, p = .032) as compared with moments when they reported no such interaction.

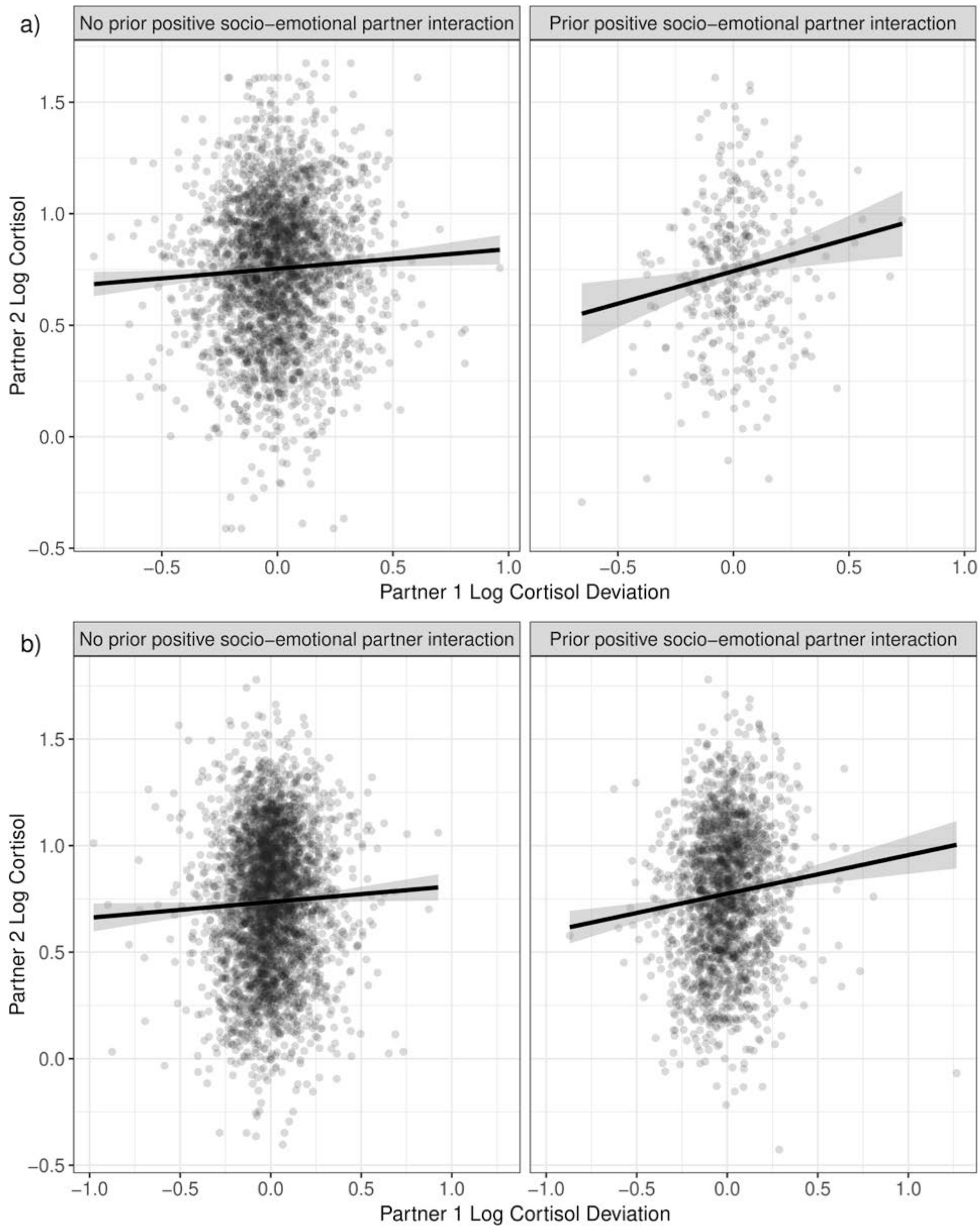

Figure 2-2: Illustration of the association between prior positive socio-emotional partner interactions and cortisol synchrony for the LL project (a) and the BCD project (b)

2.3.2. Cortisol synchrony and interindividual differences in empathy

We had hypothesized that cortisol synchrony would be greater in individuals with greater self-reported empathy. There was no significant association between cortisol synchrony and empathic concern (b = 0.01, SE = 0.01, p = .590). However, there was a marginally significant positive relationship between perspective-taking and cortisol synchrony (b = 0.02, SE = 0.01, p = .065; see *Table 2.3* Model D). Cortisol synchrony was only significant in participants with high but not in those with low perspective-taking (see *Figure 2-3*). Furthermore, individuals with greater perspective-taking demonstrated higher cortisol levels, on average (b = 0.09, SE = 0.04, p = .034).

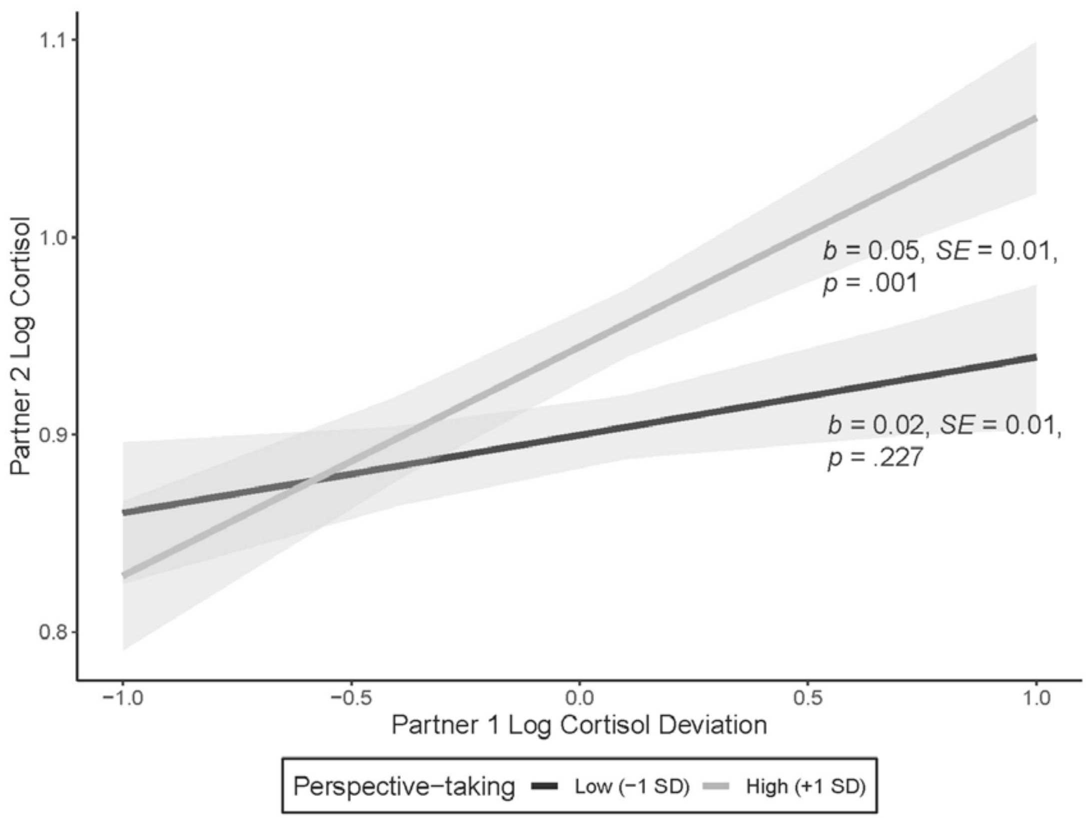

Figure 2-3. Cortisol synchrony for individuals with low (-1 SD) and high (+1 SD) perspective-taking

2.3.3. Explained variance

Explained variance due to fixed model effects ranged from 38% to 62% for the LL project and from 47% to 65% for the BCD project. Explained variance due to fixed and random model effects ranged from 57% to 73%% for the LL project and from 64% to 74% for the BCD project. Variability in cortisol levels was situated at 92/93% on the momentary level, 6/5% on the person level, and 2/2% on the couple level for the LL/BCD projects, respectively.

2.4. Discussion

Health is closely linked in romantic partners across the adult lifespan (Di Castelnuovo et al., 2009). This interconnection becomes especially salient and relevant for individual health in old age, with the onset of physical limitations and chronic conditions (Di Castelnuovo et al., 2009; Hoppmann & Gerstorf, 2009). The current study aimed to elucidate one potential biological mechanism that could contribute to our understanding of previously observed health concordance in couples: synchrony in physiological stress responses. Specifically, we investigated cortisol synchrony as dyadic associations in fluctuating cortisol levels in the everyday lives of older adult couples from two different geographical locations. We found significant dyadic cortisol linkages in older romantic partners, but not in random partner pairings. Cortisol synchrony was greater in moments when the partner was present (LL project) and in moments when partners reported a prior positive socio-emotional interaction with their significant other (LL project and BCD project). Furthermore, there was a trend for synchrony being higher in individuals with better perspective-taking abilities (BCD project).

2.4.1. Cortisol synchrony in older couples

We found that romantic partners' cortisol levels were significantly linked, such that an individual's cortisol was higher in moments when their partner's cortisol was higher than usual for that time of day. Thus, we extend previous daily life studies with younger participants (Papp et al., 2013; Saxbe et al., 2015; Saxbe & Repetti, 2010) by demonstrating within-couple associations in naturalistic fluctuations of salivary cortisol in two different older adult samples. In line with previous research, no significant cortisol synchrony was found for randomly paired partners (Saxbe et al., 2015). This indicates that interdependence in cortisol levels cannot solely be explained by joint diurnal cortisol changes or other non-couple-specific habits including typical meal times or activity patterns. One mechanism contributing to linked cortisol fluctuations may be that HPA axis activity is not only elicited by own stressors but that individuals also show 'empathic' stress responses when their partner is facing challenges (Engert et al., 2014). Furthermore, partner interactions may stimulate the release of oxytocin, which in turn potentially down-regulates HPA activity in both partners (Heinrichs et al., 2003). Yet, synchrony may not just be based on interpersonal processes. We cannot rule out that it could also be the by-product of shared experiences or other shared contexts including posture or temperature. For example, both partners being faced with the same stressor could elicit linked cortisol changes. However, physiological synchrony can be manipulated in the lab by different instructions or type of interactions (Coutinho et al., 2018; Nelson et al., 2017). Thus, synchrony may result from both interpersonal processes and joint experiential context. Future research is needed to examine the relative contribution of both.

2.4.2. Cortisol synchrony and time-varying everyday social contexts

We found partial support for our expectation that cortisol synchrony is greater in moments when the partner is present as compared with moments when the partner is absent. Partner presence emerged as a significant moderator of cortisol synchrony in the LL sample but not in the BCD sample. Compared with the LL project, the BCD sample was older and had a higher number of health conditions. When facing health constraints, partner presence may not only be sought out by choice (e.g. to connect with one another) but also necessitated by physical limitations (e.g. not feeling confident to leave the house by oneself). Future research on cortisol synchrony should thus consider different motivations for seeking out social contexts in daily life. Furthermore, cortisol levels peak about 20 min after the onset of external events or following changes in emotional states (Kudielka et al., 2012). Yet, cortisol levels and reports regarding partner presence were collected concurrently in both studies. Consequently, the delay in cortisol responses may have obscured the moderating effect.

In both studies, cortisol synchrony was greater when partners reported having had a positive interaction with their partner that involved feeling understood and appreciated (LL project) or recruiting help or seeking closeness (BCD project). These findings are in line with the Physiology of Romantic Pair Bond Initiation and Maintenance Model (Mercado & Hibel, 2017), which suggests that neuroendocrine activation in a non-stress context promotes social affiliative and social bonding processes, thereby contributing to relationship maintenance. In these instances, HPA axis activation may support approach behaviour towards the partner, paying attention to social cues from the partner, and feelings of connectedness (Mercado & Hibel, 2017).

Of note, elevated cortisol levels may not only promote attunement and closeness, but also induce greater attention to negative information such as disapproval and criticism (Shirtcliff et al., 2014). Correspondingly, synchrony has been demonstrated during negative partner interactions including conflict and may, in this context, be linked with escalating negative affect (Mercado & Hibel, 2017; Timmons et al., 2015). This may explain why research with younger samples has demonstrated that physiological synchrony was higher during negative rather than positive partner interactions (Coutinho et al., 2018). The current study specifically focused on positive partner interactions because, first, older adults prioritize positive social interactions and, second, they report more time engaged in positive social interactions with close others (Carstensen et al., 2003). Future research with younger, middle-aged, and older samples needs to investigate whether cortisol synchrony during positive partner interactions may increase whereas cortisol synchrony during negative partner interactions decreases across the adult lifespan. The current work provides initial evidence that cortisol synchrony following positive interactions may differ between older and very old couples, possibly due to age-related decreases in HPA flexibility (Charles, 2010).

In addition to the predicted effects and replicating previous studies, older adults in the BCD sample generally displayed lower cortisol levels when their partner was present and when they report having had a prior positive socio-emotional interaction with their partner (Ditzen et al., 2008; Papp et al., 2013). This speaks to the potential protective effect of positive romantic relationships on physiological stress responses and health in general (Ditzen et al., 2008; T. W. Smith, 2019). However, these associations were not significant in the younger and healthier LL sample. This may be related to BCD participants depending more on each other for support to manage daily life. Of note and in line with this assumption, the item measuring positive socio-emotional partner interactions in the BCD project asked for practical support (help/closeness), whereas the item used in the LL project had a greater emotional emphasis (understanding/appreciation).

2.4.3. Cortisol synchrony and interindividual differences in empathy

Cortisol synchrony tended to be higher for individuals with greater self-reported perspective-taking. This dovetails with experimental research demonstrating that partners who are instructed to take one another's perspective show greater synchrony in salivary alpha-amylase, as compared with couples being instructed to be mindful or to focus on their own perspective (Nelson et al., 2017). Yet, in contrast to findings from a younger sample (Engert et al., 2014), empathic concern showed no such association in the present study. In light of declining cognitive resources, the preservation of the ability to accurately infer and understand a partner's mental and emotional states may be particularly relevant in old age (Kunzmann & Wrosch, 2017). In contrast, feelings of sympathy and compassion towards others may be less relevant for covariance in older adults' daily physiology. Findings have to be interpreted in light of empathy data only being available for a subset of participants in the BCD project, contributing to limited power to detect differential associations with subfacets, and need to be replicated in future research.

Furthermore, cortisol levels were higher, on average, in older adults with greater perspective-taking. There is well-established evidence that empathy is important for relationship quality (e.g., Grühn et al., 2008). However, if cortisol responses are frequently transmitted from one partner to the other, this could have detrimental health consequences in the long run due to HPA-axis dysregulation (Adam et al., 2017; Kiecolt-Glaser & Wilson, 2017). Being closer, or more 'in sync', with a significant other may then increase the risk of depressive symptoms and an early onset of chronic disease (Kiecolt-Glaser & Wilson, 2017). Thus, future research needs to consider cortisol synchrony during positive vs. negative partner interactions not just in the context of relationship functioning, but also its potential positive and negative health ramifications further down the road.

2.4.4. Strengths, limitations, and future directions

Strengths of the current project include using a daily life approach and replicating findings across two couple data sets. A large share of variability in cortisol levels can be found on the momentary level, while only a small amount is related to stable between-person differences. The time sampling approach capitalizes on the underlying time-varying social dynamics by collecting psychological and physiological data across a variety of different situations to identify systematic linkages over time (Timmons, Baucom et al., 2017). However, a drawback to this approach is that all associations are correlational and we can thus not pinpoint causal pathways. We assume that cortisol synchrony may contribute to health concordance in couples. Yet, to test this assumption longitudinal studies examining changes in synchrony and couple's health over time are needed. In addition, the ideal sampling plan for everyday-life assessments is subject to debate. To reduce participant burden but still capture a representative slice of couples' daily lives, we decided to sample salivary cortisol 5 and 7 times a day for 7 days. Future studies should collect more intense daily measurements for a shorter period of time (e.g., brief electronic assessments and salivary cortisol samples every hour) to be able to look at time-ordered associations and direction of transmittance between partners.

In line with prior research, empathy was measured via global self-reports. However, we also recognize that empathy may vary across different daily life situations. Future studies should assess empathy on a trait and state level, to disentangle associations of cortisol synchrony with stable vs. time-fluctuating empathy. We focused on two specific types of positive socio-emotional partner interactions. It remains to be determined whether cortisol synchrony is also heightened during other interactions including moments of sharing and intimacy.

Finally, we used community-dwelling samples that were relatively healthy and reported relatively high relationship satisfaction. Future research is needed to examine whether results generalize to couples with a lower rate of positive and a higher rate of negative partner interactions, and to older adults with significant health limitations. We would expect cortisol synchrony to be less pronounced in older adults with severe health conditions and cortisol synchrony during positive interactions to be less apparent in high-conflict couples.

2.4.5. Conclusions

Romantic partners' health and well-being are closely intertwined (Kiecolt-Glaser & Wilson, 2017). The current study investigated one biological mechanism of such linkage, namely synchrony in cortisol fluctuations throughout older couples' daily lives. We found that older adults displayed higher cortisol in moments when their partner's cortisol was also higher than usual. Such cortisol linkage was more pronounced in moments when the partner was present, and when individuals reported a prior positive socio-emotional partner interaction. Notably, the link between positive socio-emotional interactions and synchrony was less strong with older age. Finally, greater perspective-taking may be linked with greater cortisol synchrony in couples. To understand whether cortisol synchrony may carry implications for older adults' longer-term relationship functioning and health it is necessary to move beyond the daily context. This was the aim of the next chapter.

Chapter 3: Consequences of cortisol synchrony for relationship quality and health

A version of this chapter is under review for publication, titled ‘You’re under my skin: Long-term relationship and health correlates of cortisol synchrony in older couples’.

3.1. Introduction

Individuals in social systems such as families exert reciprocal influence on each other (Proulx & Snyder, 2009; R. L. Repetti et al., 2011). Such social dynamics are particularly strong in couples, because romantic partners live together, care about each other, and engage in daily exchanges (Schoebi & Randall, 2015). One way to quantify the degree of interconnectivity in partners is cortisol synchrony, i.e., the extent to which everyday fluctuations in this prominent stress hormone are linked within a couple (e.g. Papp et al., 2013). There is a distinct lack of research on the implications of micro scale couple dynamics for individual functioning, with a particular shortage of data from older adult samples. Synchrony may be even more pronounced in old age, as older couples spend more time with each other and depend more on each other for support due to age-normative changes in health (Hoppmann & Gerstorf, 2014). Leading connected lives possibly constitutes a double-edged sword: Cortisol synchrony may promote positive relationship functioning (Mercado & Hibel, 2017), while it could also mean that stress responses (frequently transmitted between partners) eventually accumulate over time and result in negative health outcomes (Timmons et al., 2015). The current study aimed to elucidate such long-term correlates of cortisol synchrony in older couples. Specifically, we explored older couples’ everyday cortisol synchrony in relation to relationship satisfaction and a biological health marker (non-HDL cholesterol) measured three times over 3 years.

3.1.1. Cortisol synchrony in couples

Social relationships are of crucial importance for our health and well-being, and this is particularly true for older adults (Carstensen et al., 2003; R. L. Repetti et al., 2011). With changed perceptions of time left to live, priorities shift towards spending more time in meaningful interactions with close others including romantic partners (Carstensen et al., 2003). Consistent with this notion, longer term changes in mental and physical health are closely intertwined in older couples (Hoppmann et al., 2011; Kiecolt-Glaser & Wilson, 2017). Recent research has ventured beyond looking at interconnections in long-term longitudinal health trajectories, to also consider the daily life mechanisms that may contribute to such overall concordance. Specifically, we and others have shown that romantic partners covary in moment-to-moment fluctuations of physiological indices in daily life – a phenomenon that has been coined physiological synchrony (Engert et al., 2018; Liu et al., 2013; Pauly, Michalowski, Drewelies et al., 2019; Timmons et al., 2015). These studies have primarily been conducted with younger and middle-aged samples. Yet, we have reason to assume that such daily dynamics in dyads are particularly pronounced in older partners due to their greater focus on maintaining positive close social relationships (Carstensen et al., 2003).

Physiological synchrony may be particularly interesting to look at with regards to cortisol, a stress hormone that is released when one of our body's most prominent stress systems, the hypothalamic-pituitary-adrenal (HPA) axis, is activated. Cortisol, which can be measured in saliva, has been shown to be responsive to social stimuli (DeVries et al., 2003). As an illustration, thinking deeply about one's romantic partner and relationship has been linked with concurrent increases in cortisol, relative to thinking about a friendship, in young women (Loving et al., 2009). Furthermore, there is accumulating evidence that dysregulated cortisol secretion plays a major role in shaping longer term health (Adam et al., 2017; Dekker et al., 2008; Hoppmann et al., 2016). For example, dysregulated cortisol secretion, which can result from repeated prolonged HPA axis activation, has been associated with inflammatory disorders, obesity, and overall mortality (Adam et al., 2017). Consequently, investigating everyday cortisol synchrony in older couples promises meaningful insights into how daily social dynamics get ‘under the skin’ to affect longer term relationship functioning and health.

3.1.2. Cortisol synchrony and relationship satisfaction

Cortisol synchrony may be a key facet of relationship functioning. The conceptual model of bio-behavioural synchrony (Feldman, 2012) highlights the importance of similarity in physiological responses between attachment partners for behavioural coordination and the formation of affiliative bonds. Experimental studies have shown that synchrony may promote the ability to consider and perceive others’ psychological states, thereby enhancing understanding and compassion towards the partner (Engert et al., 2014; Valdesolo & Desteno, 2011). This is supported by neuro-imaging research showing that synchrony activates brain areas associated with social cognition, self-other expansion, and behavioural observation (Cacioppo et al., 2014). Taking these ideas one step further, the Physiology of Romantic Pair Bond Initiation and Maintenance model (Mercado & Hibel, 2017) proposes that synchrony in physiological stress systems plays a critical role for relationship maintenance. Specifically, the model suggests that coordinated activation of the HPA axis in a non-stress context facilitates approach behaviour towards the partner, attentiveness to cues from the partner, and emotional connectedness. Laboratory research also suggests that synchrony may foster cooperation through facilitating coordinated responses to external events (Miles et al., 2017). Thus, greater cortisol synchrony may be associated with greater relationship satisfaction, and with positive changes in relationship satisfaction over time.

3.1.3. Cortisol synchrony and health

While cortisol synchrony is expected to be associated with greater relationship satisfaction, it may also be associated with worse health outcomes. Being in tune with one's partner may be adaptive and important for promoting closeness and empathy (Engert et al., 2014). Yet, such close linkage may entail sharing of positive as well as negative experiences and psychological states. Consequently, greater synchrony could also facilitate physiological spillover from one partner to the other (Kiecolt-Glaser & Wilson, 2017). If this happens repeatedly in an everyday context, it could ultimately lead to wear and tear on the body with ramifications for other bodily systems (McEwen, 1998).

The present project targets blood lipid levels as a potential biological mechanism linking cortisol synchrony with cardiovascular disease risk, a particularly salient condition in older adults (Rosmond & Björntorp, 2000). Lipoprotein analysis (lipid profile) measures the total amount of fatty substances (cholesterol) in the blood. Too much cholesterol in the blood can build up inside arteries, forming plaque. Low Density Lipoprotein (LDL) cholesterol contributes to plaque buildup (atherosclerosis), whereas High Density Lipoprotein (HDL) cholesterol helps move LDL cholesterol out of the bloodstream and carries it back to the liver for disposal. Non-HDL cholesterol is calculated by subtracting HDL cholesterol from total cholesterol. Recent evidence shows that non-HDL cholesterol may be better predictor of cardiovascular risk than LDL cholesterol (Bergmann, 2010; Boekholdt et al., 2012; Sniderman et al., 2011; Wongcharoen et al., 2017).

Greater stress-related cortisol secretion and higher total cortisol output have been associated with less favorable lipid profiles (Rosmond et al., 1998; Veen et al., 2009). Furthermore, increased cortisol responses to stressors in the laboratory and elevated daily life cortisol secretion have been linked with aggravated plaque in healthy middle-aged and older adults (Dekker et al., 2008; Hajat et al., 2013; Hamer et al., 2010). Consequently, if in the context of high cortisol synchrony the HPA axis does not only get activated every time an individual faces a stressor, but also every time their partner faces a stressor, this may contribute to unfavorable changes in lipid levels over the long term.

3.1.4. The current study

This study aimed to connect everyday cortisol synchrony in older couples to longer-term trajectories of relationship functioning and health. To do so, we used data from a larger project on spousal health dynamics in old age (Pauly, Michalowski, Nater et al., 2019). We modeled trajectories separately for men and women, considering gender differences in marriage-health dynamics as well as sex differences in lipid levels (Kiecolt-Glaser & Wilson, 2017; Palmisano et al., 2018). We hypothesized that couples with greater cortisol synchrony report greater relationship satisfaction, and greater increases in relationship satisfaction over a period of 3 years. However, at the same time, greater cortisol synchrony may also take a toll on an individual’s physiological systems long term, as indicated by greater non-HDL levels, and an increase in non-HDL levels over time. Several covariates at the momentary and individual level linked with relationship functioning, lipid levels, and cortisol secretion were considered in the analysis, including age, ethnicity, education, time since waking, exercise, alcohol/caffeine/food intake, and sleep (Boekholdt et al., 2012; Erol & Orth, 2014; Strahler et al., 2017).

3.2. Methods

3.2.1. Participants

Data are from 85 heterosexual older couples (*M* age = 71.2 years, *SD* = 6.1, range: 60 to 87 years; 58% White; 37% at least some college education) living in Vancouver, Canada. Participants rated their health as good (*M* = 3.3; *SD* = 1.0; 1 = poor, 5 = excellent health), reported low to moderate amounts of perceived stress (*M* = 12.5 out of 40, *SD* = 5.3; Perceived Stress Scale-10; Cohen & Williamson, 1988), and had been married to their current partner for an average of 40.5 years (*SD* = 13.6). Couples were recruited through existing research participant pools, newspaper and online advertisements, community organizations, and community postings. In order to be eligible for participation, both partners of each couple were required to participate; they had to be at least 60 years old at the time of participation; fluent in English, Mandarin, or Cantonese; able to read newspaper sized print and have auditory capability to hear an alarm. Furthermore, for reasons unrelated to the present work, participants could not have any medical conditions for which physical activity would be contraindicated or self-reported neurodegenerative conditions (e.g., stroke or Alzheimer's disease). From an original sample of 129 older couples entering the study, nine couples did not complete the daily life assessments and data from one couple were excluded for language comprehension reasons. Twenty-eight couples were not asked to provide saliva samples due to medical conditions related to HPA dysregulation such as thyroid dysfunction. Cortisol data of two couples were missing and data of four couples were excluded due to aberrant cortisol profiles, possibly due to taking medications influencing HPA axis activity like antipsychotics. The 170 retained participants (85 couples) did not differ from excluded participants in terms of age, self-rated health, body mass index, ethnicity, education, or retirement status. Participants provided informed consent, and the study was approved by the university's clinical research ethics board. Each participant received $200 CAD as reimbursement for full study participation.

3.2.2. Procedure

As part of the baseline assessment (T1), each couple was asked to participate in two interview sessions and a daily-life assessment protocol. For 7 days, participants answered brief electronic questionnaires and collected saliva samples using Salivettes (Sarstedt, Germany) at five daily assessment points. Furthermore, participants went to a commercial laboratory (Lifelabs) for a fasting blood draw at a convenient time during the daily life assessment period. One and two years after study entry (T2 and T3), participants were contacted to complete the same measures again with the exception of the daily life assessments, and to also go for a blood draw. Partners were able to complete these follow-ups together or alone and were reimbursed $50 CAD for each assessment they completed. Retained participants at both follow-ups did not differ from non-retained participants in terms of age, self-rated health, body mass index, ethnicity, and education. Out of 170 individuals with complete data at T1, 121 individuals returned for the first follow-up (T2; M = 12.4 months after study entry, SD = 1.3, range = 11.1-16.8) and 119 individuals returned for the second follow-up (T3; M = 24.2 months after study entry, SD = 1.6, range = 23.0-30.3), with 102 individuals completing both.

3.2.3. Measures

3.2.3.1. Cortisol synchrony

At each momentary assessment point, participants were asked to take a synthetic stick out of a pre-labelled tube (Salivettes; Sarstedt, Germany) indicating time point and day of study, place it in their mouth, and remove it after finishing the assessment or when the synthetic stick was saturated with saliva. To capture cortisol's diurnal rhythm (Kudielka et al., 2012), participants collected five samples spaced approximately evenly across the day (waking, waking plus 30 min, 11 AM, 4 PM, 9 PM). Participants were instructed to keep saliva samples in their personal fridge or freezer. After being returned to the lab, they were stored at -31°C until shipped to Clemens Kirschbaum's laboratory in Dresden, Germany, for cortisol assays. Due to skewness of the distribution, cortisol values were log-transformed for analysis (M = 0.99 $\log_{10}$nmol/L, SD = 0.40). For each time point, participants also recorded the sample number and accidentally swapped samples were reordered before analyses. Participants provided a mean of 32 (91%) out of 35 scheduled saliva samples. Multilevel models (R lme4 package; Bates et al., 2015) were used to estimate a cortisol synchrony score for each couple. Specifically, a person's cortisol value was modeled taking into account time since waking, momentary control variables (whether participants had exercised, consumed alcohol, caffeine, or food, or fallen asleep since the previous assessment; Strahler et al., 2017), and their partner's deviation from their mean cortisol for that time of day. Random slopes of the association between own and partner's cortisol were extracted from models to indicate the amount of dyadic covariation in cortisol fluctuations (i.e. synchrony) for each couple (M = 0.04, range = -0.04 to 0.13, SD = 0.03).

3.2.3.2. Relationship satisfaction

Relationship satisfaction was assessed using the Relationship Assessment Scale (RAS; Hendrick, 1988). The RAS is global measure of general relationship satisfaction and has demonstrated acceptable reliability and validity among age-diverse couples (Hendrick et al., 1998; Vaughn & Baier, 1999). Scores were averaged across 7 items, which were rated on a 5-point Likert scale from 1 = "not at all" to 5 = "very much" (T1: M = 4.19, SD = 0.71, T2: M = 4.18, SD = 0.72, T3: M = 4.19, SD = 0.71). Internal consistency of participants' ratings was high in this sample (Cronbach's α = .90, .92, .91 for T1, T2, and T3).

3.2.3.3. Non-HDL cholesterol

Participants were asked, but not required, to give a blood sample annually. The blood sample required at least 10 hrs of fasting before arriving at a commercial lab in their community, to have blood drawn by a trained phlebotomist. Blood assays included total cholesterol and high-density lipoprotein (HDL) cholesterol. Lipoprotein profiles are a well-evidenced marker for cardiovascular risk and can be reliably measured in venous blood samples (Bachorik et al., 1991; Di Angelantonio et al., 2009). Non-HDL cholesterol was calculated as total cholesterol minus HDL-cholesterol (T. J. Anderson et al., 2013; T1: $M = 3.40$, $SD = 0.89$; T2: $M = 3.43$, $SD = 0.83$; T3: $M = 3.60$, $SD = 0.93$). The optimal non HDL-cholesterol level is less than 2.60 mmol/L (T. J. Anderson et al., 2016).

3.2.3.4. Covariates

A background questionnaire assessed for pertinent individual difference characteristics, which were used as covariates in the models (age, ethnicity, education) to predict initial levels of and changes in study outcomes.

3.2.4. Statistical analyses

Dyadic latent growth curve structural equation models were estimated in MPlus 8.3 (Muthén & Muthén, 1998-2017), following a statistical approach outlined by Peugh et al. (2013). Maximum likelihood estimation with robust standard errors was used. Separately for men and women, these models defined an intercept as the expected outcome (relationship satisfaction or non-HDL cholesterol) at T1 as well as a slope estimate for the expected linear change over three years; see *Figure 3-1*. Due to the fact that participants varied in the time they returned for the follow-up assessments, slope loadings of all three measurements were set individually (TSCORES option). Models freely estimated fixed and random slopes and intercepts and intrapersonal intercept-slope covariances. Owing to the dependency of data of romantic partners, models further estimated intercept-slope covariances and residual covariances of outcomes between partners. Synchrony was added as a time-invariant covariate (measured at T1) to predict male and female intercepts and slopes. Age, ethnicity, and education were included as control variables. Due to estimating random slopes of change over time for each participant and, consequently, outcome variance varying across subjects, overall fit statistics were not available. Instead, we report the reduction in residual variance of the respective indicator (intercept or slope) when synchrony is added to the model (*Pseudo-R^2*) and a test for nested models using log-likelihood values.

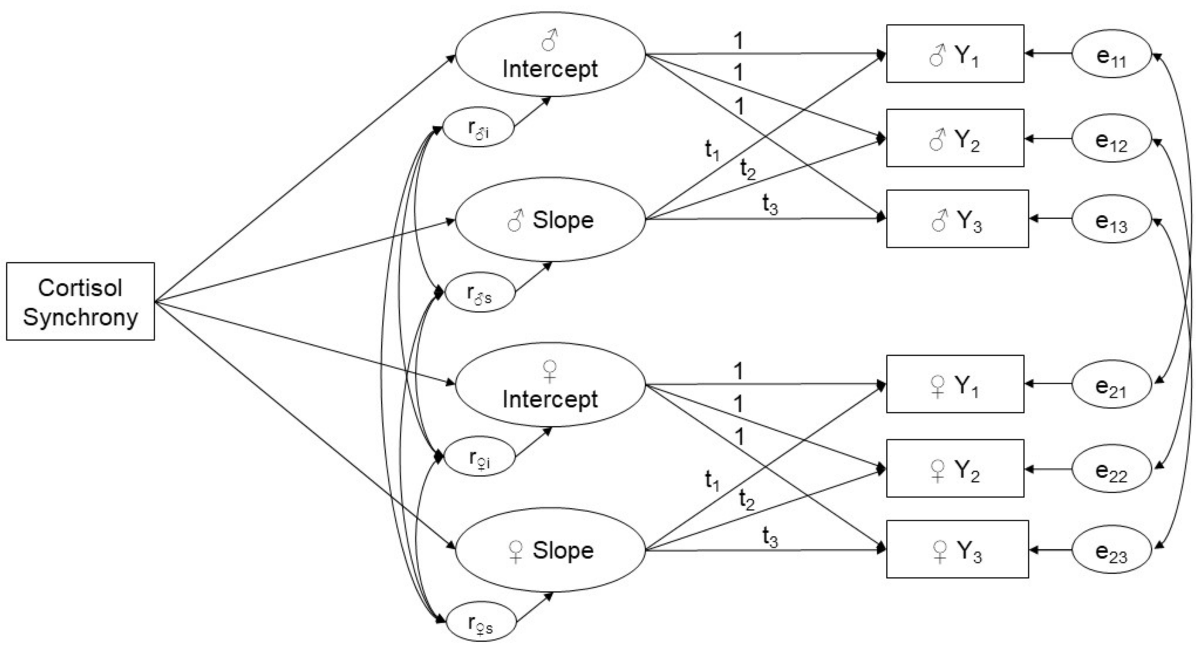

Figure 3-1: Generic model used for the analysis of associations between cortisol synchrony (measured at T1) and men's and women's initial levels of and changes in relationship satisfaction and non-HDL cholesterol across three yearly assessments

3.3. Results

Table 3.1 displays descriptive statistics and inter-correlations of central study variables. Greater cortisol synchrony was associated with higher non-HDL cholesterol levels at T1 (r = .18, p = .020) and T3 (r = .22, p = .029). There were no bivariate associations of cortisol synchrony with relationship satisfaction at any of the three assessment points. Non-White participants were older (r = .21, p = .005), were less likely to have completed a university degree (r = -.27, p < .001), and reported lower relationship satisfaction at all three assessments (T1: r = -.36, p < .001; T2: r = -.33, p < .001, T3: r = -.30, p < .001). Having a university education was linked with higher relationship satisfaction (T1: r = .25, p = .001; T2: r = .31, p = .001, T3: r = .25, p = .006). A repeated measures ANOVA showed that neither participants' self-reported relationship satisfaction nor their non-HDL cholesterol levels significantly differed between the three yearly assessments (female relationship satisfaction: F(2, 100) = 0.27, p = .768; male relationship satisfaction: F(1.14, 72.07) = 1.82, p = .178; female non-HDL cholesterol: F(2, 74) = 1.23, p = .297; male non-HDL cholesterol: F(1.72, 66.87) = 0.99, p = .367).

Table 3.1: Means, standard deviations, and intercorrelations of central study variables (N = 80-170)

Variable	Women *M* (*SD*)	Men *M* (*SD*)	2	3	4	5	6	7	8	9	10
1. Age	69.98 (*5.57*)	72.38 (*6.32*)	-.05	.21**	-.10	-.03	.03	-.04	-.11	-.10	-.10
2. Education (1 = university degree)	0.36	0.38		-.27**	.06	.25**	.31**	.25**	.05	-.09	-.09
3. Ethnicity (1 = Non-White)	0.42	0.42			-.09	-.36**	-.33**	-.30**	-.15	-.16	-.19
4. Cortisol synchrony T1	0.04 (*0.03*)	0.04 (*0.03*)				.05	.00	.11	.18*	.13	.22*
5. Relationship satisfaction T1	4.07 (*0.81*)	4.32 (*0.58*)					.92**	.79**	.09	.05	.10
6. Relationship satisfaction T2	4.01 (*0.82*)	4.34 (*0.55*)						.81**	.01	-.01	.04
7. Relationship satisfaction T3	4.10 (*0.84*)	4.29 (*0.60*)							.08	.05	.05
8. Non-HDL cholesterol T1	3.56 (*0.85*)	3.23 (*0.90*)								.77**	.76**
9. Non-HDL cholesterol T2	3.54 (*0.78*)	3.32 (*0.87*)									.80**
10. Non-HDL cholesterol T3	3.78 (*0.91*)	3.43 (*0.94*)									

Note. SD = standard deviation. * $p < .05$. ** $p < 0.01$.

3.3.1. Cortisol synchrony and relationship satisfaction

Results from dyadic latent growth models predicting levels and changes in relationship satisfaction can be found in *Table 3.2*. Average levels of relationship satisfaction were significantly linked between partners (b = 0.20, SE = 0.08, p = .011), whereas changes over time were not. Greater cortisol synchrony was not associated with overall levels of relationship satisfaction in men or women. However, greater cortisol synchrony was associated with a greater increase in relationship satisfaction over time in women (b = 1.62, SE = 0.59, p = .006, *Pseudo*-R^2 = .20). With regards to control variables, non-White participants reported lower relationship satisfaction (women: b = -0.50, SE = 0.16, p = .002; men: b = -0.39, SE = 0.11, p = .001) and men with college education displayed a greater increase in relationship satisfaction over time (b =0.12, SE = 0.06, p = .017).

3.3.2. Cortisol synchrony and non-HDL cholesterol levels

As can be seen in *Table 3.2*, neither overall non-HDL cholesterol levels nor change in non-HDL cholesterol levels over time were significantly linked in partners. Men, but not women, showed a positive association of cortisol synchrony with overall non-HDL cholesterol levels (b = 6.37, SE = 2.87, p = .027, *Pseudo*-R^2 = .05). Furthermore, greater cortisol synchrony was related to a greater increase in non-HDL cholesterol levels over time in women (b = 2.00, SE = 1.01, p = .048, *Pseudo*-R^2 = .05). Neither cholesterol levels nor their change over time were significantly linked with participants' age, ethnicity, or education.

Table 3.2: Parameter estimates for dyadic latent growth curve models (N = 85 couples)

	Relationship satisfaction		Non-HDL cholesterol	
Parameters	*B* (*SE*)	*p*	*B* (*SE*)	*p*
Fixed Effects				
Intercept ♂	4.64 (0.62)	<.001	3.54 (0.95)	<.001
Intercept ♀	3.34 (0.96)	.001	3.54 (1.09)	.001
Slope ♂	-0.39 (0.35)	.264	0.09 (0.50)	.863
Slope ♀	-0.32 (0.30)	.294	-0.20 (0.47)	.674
Intercept ♂ x cortisol synchrony	2.28 (2.00)	.253	6.37 (2.87)	.027
Intercept ♀ x cortisol synchrony	-1.56 (2.58)	.546	0.75 (2.68)	.780
Slope ♂ x cortisol synchrony	-0.37 (0.65)	.570	0.08 (0.90)	.932
Slope ♀ x cortisol synchrony	1.62 (0.59)	.006	2.00 (1.01)	.048
Covariance individual level				
Intercept ♂ ↔ slope ♂	-0.03 (0.06)	.638	-0.04 (0.06)	.341
Intercept ♀ ↔ slope ♀	-0.01 (0.06)	.977	-0.01 (0.14)	.973
Covariance couple level				
Intercept ♂ ↔ intercept ♀	0.20 (0.08)	.011	0.13 (0.12)	.274

Slope ♂ ↔ slope ♀	-0.03 (0.06)	.638	0.01 (0.03)	.680
Intercept ♂ ↔ slope ♀	0.02 (0.04)	.570	0.02 (0.05)	.704
Intercept ♀ ↔ slope ♂	-0.03 (0.05)	.446	0.02 (0.06)	.778
Residual ♂ T1 ↔ Residual ♀ T1	-0.01 (0.05)	.977	0.02 (0.08)	.796
Residual ♂ T2 ↔ Residual ♀ T2	-0.01 (0.02)	.816	0.01 (0.04)	.924
Residual ♂ T3 ↔ Residual ♀ T3	-0.01 (0.07)	.571	-0.08 (0.08)	.286
Model Fit				
Number of parameters estimated	39		39	
Log-likelihood	-212.25		-359.31	
$\chi 2(4)$	7.54	.110	9.83	.043

Note. *SE* = standard error. HDL = high-density lipoprotein. Cortisol synchrony was assessed at T1. Models control for participants' age, education, and ethnicity. Coefficients < |0.01| were rounded to 0.01 or -0.01. The chi-square difference test compares full models with models that omit synchrony as a predictor, utilizing log-likelihood values and scaling correction factors obtained via maximum likelihood estimation with robust standard errors.

3.3.3. Model fit

Model fit was evaluated using a chi-square difference test for nested models based on log-likelihood values and scaling correction factors. For non-HDL cholesterol, the full model provided better fit as compared with a model that omits synchrony as a predictor ($\chi^2(4) = 9.83$, $p = .043$), whereas the difference was not significant for relationship satisfaction ($\chi^2(4) = 7.54$, $p = .110$).

3.4. Discussion

When reaching old age, we become increasingly intertwined with our romantic partners (Hoppmann & Gerstorf, 2009). With the onset of physical limitations, individuals may depend on their significant other to help them manage daily tasks (e.g., give them insulin shots) and reach their socio-emotional goals (e.g., drive them to visit grandkids). This increased interdependence, combined with a prioritization of close relationships, emphasizes the marked importance of couple dynamics for older adult's health and well-being (Kiecolt-Glaser & Wilson, 2017). Yet, not much is known about the possible double-edged sword of everyday physiological linkage in older adult couples for shaping aging trajectories. The current study aimed to investigate long-term correlates of one indicator of such linkage, namely the extent to which partners covary in their cortisol fluctuations while engaging in their day-to-day activities (cortisol synchrony). For men, we found that greater cortisol synchrony was associated with greater levels of non-HDL cholesterol but not with their change over time. Furthermore, cortisol synchrony was not related to levels or change in men's relationship satisfaction over time. For women, greater cortisol synchrony was not associated with levels of relationship satisfaction or non-HDL cholesterol levels. Yet, it was linked with both greater increases in non-HDL cholesterol levels and also in relationship satisfaction over time. In the following, we will integrate our findings with the broader literature on physiological linkage, relationship functioning, and health.

3.4.1. Cortisol synchrony and relationship satisfaction

Contrary to our expectation, greater cortisol synchrony was not linked with levels of relationship satisfaction in older men or women. However, women with more pronounced cortisol synchrony with their partner showed greater increases in relationship satisfaction over time. Previous studies have linked physiological synchrony to both positive and negative relationship indices. For example, greater linkage in respiratory sinus arrhythmia (indicating parasympathetic activity) during laboratory tasks has been associated with higher relationship satisfaction in young to middle-aged couples (Helm et al., 2014). At the same time, greater cortisol synchrony has also been linked with higher relationship aggression in young parents and greater marital strain/disagreement in middle-aged adults (Liu et al., 2013; Saxbe et al., 2015). Other studies investigating markers of physiological arousal including salivary alpha amylase or electro-dermal activity did not find evidence for any associations between physiological synchrony and global relationship functioning (Coutinho et al., 2018; Nelson et al., 2017). Thus, associations could be marker-specific, i.e. whether parasympathetic, sympathetic, or adrenocortical functioning is measured. Markers of parasympathetic activity such as respiratory sinus arrhythmia may be more sensitive to positive interpersonal processes than stress response system markers such as cortisol (Helm et al., 2014).

Another explanation might be that dynamics differ in young and middle-aged couples, as compared with older couples. Participants in our older sample reported relatively high and stable levels of relationship satisfaction. Daily social interactions of older couples tend to be more positive and less conflictual than those of younger and middle-aged partners (Fingerman &

Charles, 2010). Thus, in younger samples, cortisol synchrony may be indicative of negative escalating patterns of conflict, and consequently more likely show associations with negative relationship characteristics. Yet, we take the finding that cortisol synchrony was linked with increases in relationship satisfaction over time in women as first evidence that daily life cortisol synchrony in old age may be an indicator of positive relationship processes. Women tend to be more aware of and to be more affected by relationship dynamics (Kiecolt-Glaser & Wilson, 2017). For example, women in distressed relationships are more likely to be affected by depression than men (Whisman, 2001). This may help explain why the link between relationship satisfaction and cortisol synchrony was specific to female participants. However, more studies are needed to contextualize associations between relationship functioning and linkage in different physiological markers with respect to age and gender differences. Future studies should also consider the quality of daily couple interactions: Synchrony during moments of disclosure and intimacy may be particularly relevant for relationship quality in old age (Laurenceau et al., 2005).

3.4.2. Cortisol synchrony and health

In accordance with prior research linking physiological synchrony to objective health indicators (e.g. increased inflammation; S. J. Wilson et al., 2018), cortisol synchrony was associated with blood lipid profiles. Laboratory studies have demonstrated that just observing one's significant other undergoing a social stressor can elicit cortisol responses (Engert et al., 2014; Engert et al., 2018). Furthermore, couples who showed greater cortisol synchrony in the lab, also showed greater linkage in cortisol levels in their daily life (Engert et al., 2018). Consequently, individuals who are more 'in sync' with their partner may to a greater extent not just display increased physiological responses to stressors they face themselves, but also to stressors that their partner is confronted with. If this happens repeatedly over time, stress-related dysfunctional physiological processes may accumulate and culminate in health risks, such as increased levels of non-HDL cholesterol (Rosmond et al., 1998). The potential downsides of close linkage to one's partner are also corroborated by results from a study with 152 knee osteoarthritis patients, which showed that the influence of worsening illness severity on the partner's mental wellbeing was stronger in couples with greater closeness (Polenick et al., 2015). Future research on synchrony's health and well-being implications could build on these initial findings to explore additional psychological, biological, and behavioural pathways to cardiovascular risk. For example, the link between physiological synchrony and health may also be explained by joint stressors or joint health behaviours. A greater amount of challenges that both partners are confronted with in daily life (e.g., financial hardship) may relate to increased daily cortisol synchrony as well as negative health outcomes. Furthermore, couples tend to be synchronous in behaviours relevant to health in daily life such as sleep or physical activity (Gunn et al., 2017; Pauly et al., 2020), which in turn can also influence cortisol levels.

We found sex differences with respect to associations between cortisol synchrony and non-HDL cholesterol between partners. For men, greater cortisol synchrony was related to higher overall non-HDL cholesterol levels, but not to changes in non-HDL cholesterol over time. For women, the opposite pattern was found: Cortisol synchrony was unrelated with overall non-HDL cholesterol levels, but it was linked with greater increases in non-HDL cholesterol over time. Biological differences in lipids and sex hormones may help explain these findings. Men in our sample were older and displayed higher non-HDL cholesterol levels, on average. Estrogen is thought to have beneficial effects on lipid metabolism, which may explain women's reduced risk for atherosclerotic cardiovascular disease before menopause (Palmisano et al., 2018). The mean relationship duration of older couples in our sample was over 40 years. Thus, it is conceivable that accumulative health effects of cortisol synchrony on average lipid levels might be visible in men earlier than in women. This may help explain why the link between cortisol synchrony and non-HDL cholesterol was level-specific in men and change-specific in women.

3.4.3. Strengths, limitations, and future directions

The current study observed cortisol synchrony in the daily life of 85 older couples, by collecting multiple saliva samples per day over a 7-day period. Thus, physiological interpersonal processes were captured as they naturally played out in couples' everyday environments, enhancing ecological validity of findings. Self-reports on couples' relationship satisfaction and an objective health marker for cardiovascular risk (blood lipid levels) were measured concurrent to daily life assessments as well as one and two years later. This provided the unique opportunity to link daily life processes with longer-term levels and changes in relationship functioning as well as health. However, there are some limitations that warrant mentioning.

Individuals who self-select to participate in a couple study may have more positive couple dynamics, as indicated by the high average levels of relationship satisfaction in the current sample. Furthermore, as common in long-term longitudinal studies, a considerable number of individuals did not return for the two yearly follow-ups, with 60% completing all three assessments. Statistical models were able to retain all participants with data for at least one year, but results may have been biased by data not missing at random related to non-observed variables.

We did not find that romantic partners covaried in longitudinal changes of relationship quality and health. This contrasts existing research tracking couples over an extended period of time (> 10 years; Erol & Orth, 2014; Hoppmann et al., 2011). Thus, although we do find systematic associations between cortisol synchrony and individual trajectories of relationship satisfaction and lipid levels, an observation period of longer than 3 years may be necessary to accurately detect dyadic covariation in long-term trajectories.

Conceptually this study is built on the idea that cortisol synchrony would act as a predictor for longer-term changes in relationship functioning and health over time, a proposition delineated from relevant psychological models. Yet, it is also conceivable that changes in relationship functioning and health may elicit changes in interpersonal physiological dynamics in older couples. We were not able to address such questions because cortisol assessments were only available at T1. Future studies should assess both relational and health outcomes as well as cortisol synchrony repeatedly over time, to shed light on potential reciprocal relationships.

By design, couples of this study were asked to participate in a week that is typical for their daily lives. Future research should consider the influence of life events such as retirement or the onset of a chronic health condition on interpersonal physiology and health of both partners. For instance, a health event may more likely put both partners at risk in case of strong physiological linkage. Finally, it remains to be determined whether the positive implications of being ‘in sync’ for relationship functioning are necessarily accompanied by negative health ramifications, or if one can exist without the other. For example, cultivating mindfulness may help build a close connection to one’s partner while reducing the physiological costs (Block-Lerner et al., 2007). This would have important implications for future couple interventions in old age, to preserve relationship quality while promoting health at the same time.

3.4.4. Conclusions

In line with prior research, the present study shows that romantic partners are linked in their daily physiological processes. To examine the implications of this linkage for relationship dynamics and health in old age, the current study examined the possibly double-edged nature of close linkage in older couples. Specifically, greater synchrony in daily cortisol fluctuations was linked with increases in relationship satisfaction in women. However, it was at the same time associated with overall greater maladaptive blood lipid levels in men, and with worsening of blood lipid levels over time in women. Thus, the current study points to one mechanism of how romantic partners may get under each other's skin, both for the good and for the bad.

Chapter 4: Cortisol synchrony and its political ideological context

A version of this chapter is under review for publication, titled ‘Political context is associated with everyday cortisol synchrony in older couples’.

4.1. Introduction

Individuals and social units such as couples operate within a broader socio-political context (Bronfenbrenner, 1999). Extending our perspective from studying micro-level psychosocial processes to also consider how ‘upstream’ or ‘distal’ factors such as culture, politics, and socioeconomics influence the functioning of smaller social units allows for a more comprehensive understanding of the functioning and development of such units (Berkman et al., 2000). Yet, we know surprisingly little about how micro-dynamics that play out in people’s daily lives are shaped by macro-level context factors. One such micro-dynamic in couples that is particularly relevant for health may be cortisol synchrony, i.e. the extent to which fluctuations in this stress hormone are linked in romantic partners’ everyday lives. This paper investigated links between couples’ cortisol synchrony and aspects of the political context in which those couples live. Specifically, we used micro-longitudinal data from 160 older German couples participating in a longitudinal panel study to examine how cortisol synchrony may differ depending on whether couples reside in federal states located further left or further right on the left-right political spectrum, controlling for individual’s own political orientation.

4.1.1. The need for linking micro-dynamics to macro-context

Although there has been extensive research on the interplay between social relationships and health, very little attention has been paid to how the broader socio-political context influences social relationships and daily social dynamics (Holt-Lunstad, 2018). Conceptual frameworks on social determinants of health highlight the importance of both proximal and distal societal factors (e.g. Berkman et al., 2000; Holt-Lunstad, 2018; House et al., 1988). Lifespan psychological and life course sociological theories also emphasize the importance of socio-political conditions for individual functioning as well as how the interplay between distal and proximal factors influences development (P. B. Baltes et al., 1998; Bronfenbrenner, 1999; Elder, 1974). Hence, there are strong conceptual grounds to examine relationships in their larger societal context and to investigate how macro-level systems may create a certain scaffolding, which ends up shaping the micro-dynamics of smaller units such as couples.

The political context may be a particularly relevant macro-level factor because politics are tied to dominant norms and values, have important ramifications for socioeconomic factors, and directly influence societal structures through laws and public policy (Jost et al., 2009). Laws and policies may create a network of opportunities and constraints for couples and define social rights and duties of family members (Hagestadt & Dykstra, 2016). As an illustration, the introduction of a policy mandating that a part of parental leave can only be taken by fathers in some European countries including Iceland, Norway, Sweden, Germany, and Portugal ('daddy quota') has increased men's use of parental leave and their levels of child involvement, and contributed to a more equal division of household tasks (Boll et al., 2014; Kotsadam & Finseraas, 2011). For older adults, policies aimed at reducing the impact of the 'motherhood penalty' on women's pensions may allow couples to retire at the same time and contribute to older women being less financially dependent on their husbands.

Despite repeated calls for linking the macro with the micro, distinctly little empirical research has focused on this topic (Berkman et al., 2000). Including both the micro and the macro perspective in the same study offers the singular opportunity to examine the interplay between both factors, and to shed light on unique contextual effects. In the present work, we aimed to address this gap by embedding one indicator of micro-level social dynamics among older romantic couples (interdependent fluctuations in cortisol, i.e. cortisol synchrony) in its larger socio-political context. Why did we focus on cortisol synchrony in older couples?

4.1.2. Cortisol synchrony in older couples

Ample evidence supports that romantic partners are closely linked in their overall health (Meyler et al., 2007). For example, if one partner's health takes a turn for the worse, the other one has an increased risk of experiencing the same negative health change (Saarela et al., 2019). In line with this notion, studies have repeatedly shown that psychosocial characteristics of someone's partner are associated with the health of this person cross-sectionally and longitudinally, over and above this person's own functioning (Kiecolt-Glaser & Wilson, 2017). One micro-level dynamic that has received increased attention in the past years, potentially contributing to this overall health link in romantic partners, may be the extent to which partners show dependency in their day-to-day fluctuations of hypothalamic-pituitary-adrenal (HPA) axis responses (R. L. Repetti et al., 2011). The HPA axis is one of our major stress response systems, and its activation results in the release of cortisol. Cortisol therefore seems to be a promising marker of micro-level social dynamics; it can easily be measured in saliva and has been shown to be responsive to positive and negative social situations (DeVries et al., 2003). More importantly, cortisol synchrony, defined as the dyadic covariation in cortisol fluctuations among romantic partners, may have important implications for both partners' long-term health because increased prolonged cortisol levels are connected to adverse health risks (G. E. Miller et al., 2007).

Cortisol synchrony as a micro-social dynamic is proposed to possess particular relevance in old age because older adults spend more time with their romantic partners and tend to place greater value on positive social relationships with close others, as compared with young and middle-aged adults (Carstensen et al., 2003). Furthermore, effects of exposure to different macro-contexts had time to accumulate over the life course and a more fragile health status contributing to greater dependency on external support may make older adults more vulnerable to socio-political influences. Thus, links between the macro (political context) and the micro (everyday cortisol synchrony) may be particularly visible in older couples (Gerstorf & Ram, 2012).

4.1.3. Cortisol synchrony and left-right political context

A widely-used and parsimonious organizing frame for political ideologies is to represent parties' positions as well as electoral choices on a Left-Right (L-R) political dimension (Jost, 2006). Originating from progressive revolutionaries sitting on the left side and conservative traditionalists (supporters of the monarchy) sitting on the right side of the French National Assembly during the French Revolutionary era, this scale locates liberal or progressive ideology on one end and conservative ideology on the other end (Jost et al., 2009). We would like to point out that the L-R scale, which is predominantly used in Western European countries, is conceptually closely related to the liberal-conservative scale, which is predominantly used to describe politics in Anglo-American countries. For the purpose of this manuscript and in light of study data originating from Germany, we focused on the L-R political spectrum.

There are several reasons to assume that the L-R political context may be associated with cortisol synchrony in older couples. One defining feature of a right-oriented context is a focus on traditions, a high value of order and structure, and a preference for conventional forms of behaviors and institutions (Jost et al., 2009; Thorisdottir et al., 2007). Furthermore, right-oriented ideology tends to place greater emphasis on social allegiance and in-group morality (Graham et al., 2012; McAdams et al., 2008). One could imagine that in the context of greater emphasis on traditional family values, a right-wing orientation may support greater commitment towards the relationship, greater interdependence between romantic partners, and greater financial investment in structures supporting families (Lye & Biblarz, 1993). In contrast, a left-oriented context may be focused on individual rights and self-directed values rather than on preserving harmonious relationships and conforming to social norms and strict behavioral rules (Schwartz et al., 2010). These lines of thought would support the idea that cortisol synchrony in older couples may be greater in a context characterized by right-oriented ideas.

There are also theoretical arguments supporting the opposite assumption. Left-oriented ideology has been shown to involve greater endorsement of reciprocity and fairness, equality, and caring and compassion for others (Graham et al., 2009; Graham et al., 2012; Schwartz et al., 2010). Additionally, left-wing orientation has been associated with more openness and greater demonstration of social behaviors related to openness such as smiling more, being more engaged with a conversation partner, and being less unresponsive (Carney et al., 2008). Thus, greater compassion for one's partner and greater display of interpersonal social behavior may promote cortisol synchrony in couples (Hirsh et al., 2010). Some studies also suggest that less traditional gender roles may promote relationship closeness through facilitating intimacy, self-disclosure, and open communication (Helms et al., 2019; Marshall, 2008; Peplau et al., 1993; Rubin et al., 1980). Finally, left-oriented attitudes have been linked with higher likelihood of divorce (Voorpostel et al., 2018). Thus, older couples in a left-oriented context may more likely reflect those who stayed together based on positive evaluations of their marriage rather than simply because they want to conform to external expectations. These conceptual notions suggest that cortisol synchrony would be greater in contexts characterized by left-oriented ideas.

In summary, there are several arguments supporting the hypothesis that the socio-political context (L-R ideology) might shape the extent to which older couples show linked fluctuations in cortisol in their everyday lives. However, due to the lack of prior research on this topic and due to theoretical delineations suggesting that synchrony could be higher or lower, the more left/right-oriented the context, the direction of association is unknown.

4.1.4. The current study

This paper situated micro-level dynamics (cortisol synchrony) in the macro-level context (L-R political spectrum) of the region the couples are living in. Data obtained from 160 older couples residing in 13 different German federal states, and who are part of the larger Socio-Economic Panel (SOEP), were used to examine links between political context and couples' health dynamics. For two reasons, Germany presents a particularly interesting case to examine the proposed research question. First, the current political system has emerged out of the combination of two different political regimes, a socialist system with a Western capitalist system, due to the reunification of East and West Germany in 1990. Second and partly because of this fact, Germany has a diverse multiparty system (Abedi, 2017). By comparing cortisol synchrony in couples residing in different German federal states, this study explored whether such differences between couples are related to the placement of the respective federal state of residence on the L-R political spectrum. Statistical models controlled for several covariates that have been linked with cortisol secretion, including person characteristics such as age, gender, body mass index, and education, and time-varying factors including time since waking and food intake (Stalder et al., 2016; Strahler et al., 2017). Contextual effects were disentangled from individual-level effects by also controlling for individuals' own L-R political orientation.

4.2. Methods

4.2.1. Participants

Data were obtained from 160 heterosexual older couples aged 56 to 89 years (*M* age = 72.3 years, *SD* = 5.8; 16% with university degree) who were part of a German representative longitudinal study, the German Socio-Economic Panel (SOEP; Headey et al., 2010; Wagner et al., 2007), and participated in an additional 7-day daily life assessment module. Out of 174 participating couples, 41 couples were part of the SOEP Innovation Sample (SOEP-IS; Richter & Schupp, 2015) and took part in the study as a pilot project in 2016/2017. Following the successful pilot, an additional 133 couples were recruited from the SOEP-Core in 2018. To be eligible for participation, couples had to live in the same household, have health data from at least three previous SOEP surveys, have sufficient command of the German language, and be able to read newspaper size print and hear an alarm clock. From the original sample of 174 couples, six couples dropped out, questionnaire data of two couples were lost, and cortisol data of six couples were missing or excluded due to irregular cortisol profiles. Participants in the final sample of 160 couples reported good to moderate physical health (*M* = 3.5, *SD* = 0.8; from 1 = “very poor” to 5 = “very good”) and had been in a relationship with their partner for, on average, 47.3 years (*SD* = 11.6, range: 4.2-65.8). Couples resided in different geographical locations across Germany, specifically in 13 out of the 16 German federal states (*M* = 12.3 couples per federal state, *SD* = 13.1). Participants received up to 100 € as reimbursement, contingent on the number of completed daily assessments. The data collection was ethics approved by the Humboldt University of Berlin and this data analysis by the University of British Columbia.

4.2.2. Procedure

When entering the SOEP sample, each participant completed a biographical questionnaire covering information on life history up to the first SOEP interview. Afterwards, participants took part in yearly face-to-face interviews with a set of pre-tested questionnaires. Interviews were conducted by employees of Kantar Public (Munich, Germany), an institute for political and social research. Questionnaires were mainly identical each year and covered a broad range of social, cultural, and economic topics. In addition to their usual participation in the SOEP, this sample of couples also completed a micro-longitudinal protocol, wherein various assessments were obtained 7 times a day over a period of 7 consecutive days. At each of these daily assessments, participants answered short questionnaires on a tablet and provided saliva samples. Additional background and psychosocial information was assessed at the start and end of the 7-day period. An interviewer contacted the participants on day 2 to clarify any questions. Adherence to the daily protocol was high (M = 48.2 out of 49 scheduled cortisol samples, range: 40 to 49) and participants rated the study period as typical of their daily lives (M = 4.1, SD = 1.1, on a scale from 1 = “not at all typical” to 5 = “very typical”).

4.2.3. Measures

4.2.3.1. Cortisol

At seven times each day (waking, waking plus 30 min, 10 AM, 1 PM, 4 PM, 7 PM, 9 PM), participants completed brief questionnaires on a tablet and provided saliva samples. Participants were instructed to take a synthetic stick out of a tube (Salivettes; Sarstedt, Germany) labelled with time point and day of study, place it in their mouth, roll it around until it was saturated with saliva and they had completed the questionnaire, and then put it back in the tube. Participants were instructed to keep saliva samples in their personal fridge, freezer, or at another cool location. Each participant received two additional tubes in case they lost a stick or accidentally dropped it on the floor. Samples were retrieved by interviewers and stored at -31°C until cortisol assays were performed by the Dresden LabService GmbH, Germany. Prior to analysis, cortisol values were log-transformed to obtain a normalized score distribution (*M* = 0.65 $\log_{10}$nmol/L, *SD* = 0.47).

4.2.3.2. Federal L-R political context

Data from the Manifesto Project and voting results from the 2017 German federal election were used to assign each German federal state a score on the L-R ideological space. The Manifesto Research on Political Representation (MARPOR) has been analyzing and coding the manifestos of over 1,000 political parties from over 50 countries since 1945, and their data are freely available online (Volkens et al., 2019). The project uses a coding scheme to measure each party's relative emphasis on a list of 56 policy content categories (Laver & Budge, 1992). Information on 13 topics each representing 'left' and 'right' politics is extracted and used to estimate the relative position on the L-R dimension for each party (Budge, 2013; for details see Appendix B). This L-R scale has been widely used in research and validated across different contexts (Pennings, 2011; Volkens et al., 2009). L-R data based on manifesto information of the 2017 German federal election were available for the six German parties elected into parliament (Bundestag), ordered by their position on the L-R spectrum: The Left (–41.91), Social Democratic Party of Germany (–21.44), Alliance 90/The Greens (–21.06), Free Democratic Party (+0.58), Christian Democratic Union/Christian Social Union (+2.76), Alternative for Germany (+17.43).[3] Manifesto coding for the respective parties showed acceptable inter-rater

[3] For comparison, the L-R scores for the Democratic Party and the Republican Party for the 2016 US election were -20.58 and 32.97, respectively.

reliability (Krippendorff's alpha = .74). The percentage of party endorsement in each federal state from the 2017 election was multiplied with the L-R index of the respective party and averaged to create a federal level L-R score (*M* = –8.20, *SD* = 2.26; min: –11.43 for Hamburg; max: –4.79 for Saxony). *Figure 4-1* displays the allocation of the six German parties and 13 German federal states on the L-R scale.

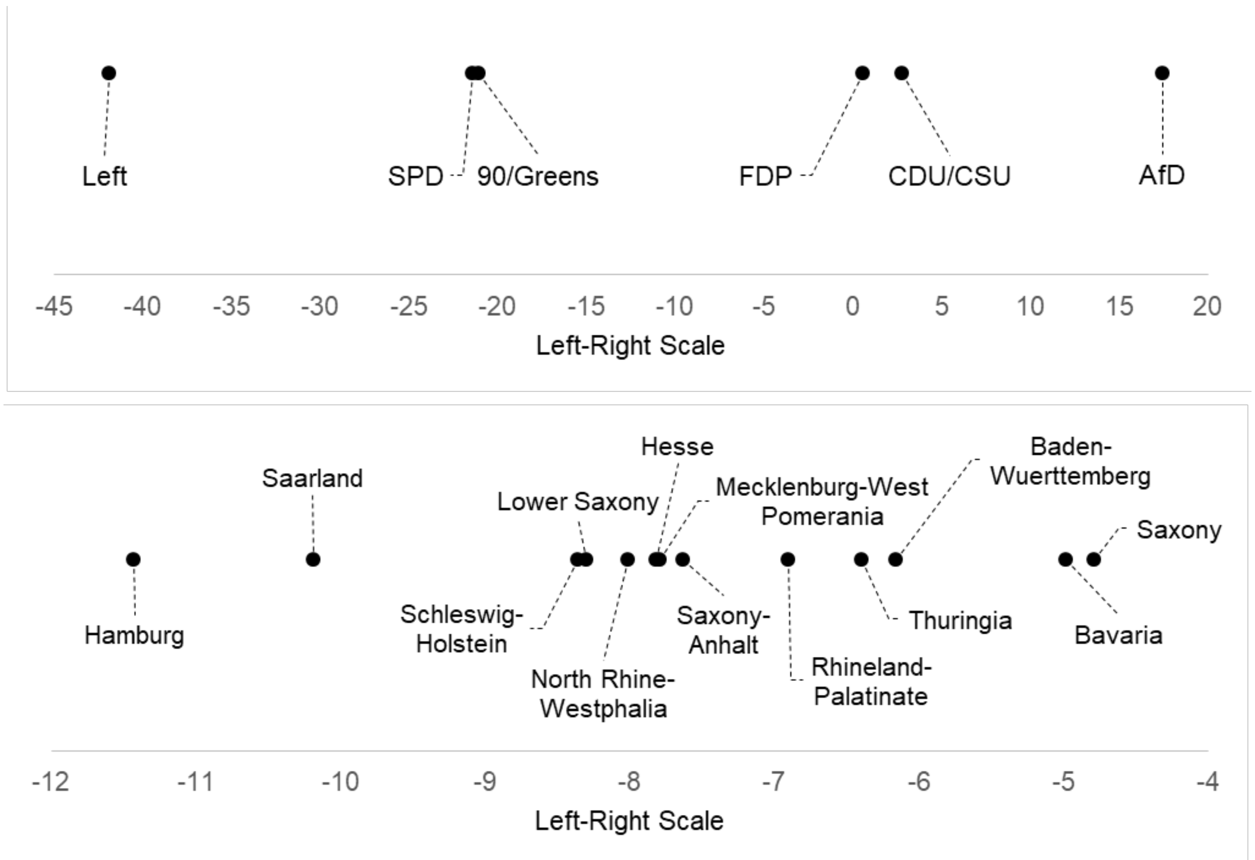

Figure 4-1: Placement of German political parties and federal states on the Left-Right scale

4.2.3.3. Person-level covariates

Information on participants' age, gender, body mass index, and education was collected during the face-to-face interview. Individual-level L-R political orientation was measured in 2014 (and not in following years) by asking participants to rate their own political views on a scale from 0 (completely left) to 10 (completely right). Participants in this study had individual L-R orientation of, on average, 4.83 (SD = 1.53) on the 0 to 10 scale.[4]

4.2.3.4. Time-varying covariates

At each momentary assessment point, participants reported whether they had consumed food, alcohol, caffeine, or nicotine, taken medication or other drugs, taken a cold shower, brushed their teeth, or engaged in physical activity in the past hour. The questionnaires during the day (3-7) additionally asked whether participants had taken a nap in the past hour. In a preliminary step, all momentary covariates were included into multilevel models to predict cortisol values. Only prior food intake showed a significant association and was retained for subsequent models, for reasons of parsimony. Additionally, models contain a term indicating time since waking and time since waking squared to account for cortisol's diurnal rhythm.

4.2.4. Statistical analyses

The nested data structure (momentary assessments nested within individuals nested within couples) was accommodated using a multilevel modelling framework. Data were prepared for analysis by separating partners' cortisol scores into a time-varying (fluctuations) component and systematic diurnal trends. Specifically, for each momentary cortisol assessment, a cortisol deviation score was calculated as the difference between the partner's usual cortisol level for that time of day and that specific assessment (*partner cortisol deviation*). These deviation scores were then used as predictors in a three-level multilevel model designed to examine differences in couples' cortisol synchrony and how they were related to federal-level L-R political context.

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[4] Data on individual L-R political orientation were not available for six individuals. Missings were replaced using single imputation. Findings do not differ if these individuals and their partners are excluded from models.

Specifically,

$$logCortisol_{tic} = \beta_{0ic} + \beta_{1ic}PartnerCortisolDeviation_{tic} + \beta_{2ic}TimeSinceWaking_{tic} + \beta_{3ic}TimeSinceWaking_{tic}^2 + \beta_{4ic}PriorFood_{tic} + e_{tic} \quad (1)$$

where the repeated measures of cortisol obtained at occasion *t* from person *i* who is part of couple *c*, $logCortisol_{tic}$,, are modeled as a function of person-specific coefficients that indicate expected waking cortisol, β_{0ic} (intercept); extent of cortisol synchrony, β_{1ic}; relations with time-varying covariates, β_{2ic} to β_{4ic}; and residual error, e_{tic}, that is assumed normally distributed with standard deviation σ_e. The person-specific coefficients are in turn modeled as a function of person-level and couple-level variables. Specifically,

$$\beta_{0ic} = \gamma_{00c} + \gamma_{01c}Age_{ic} + \gamma_{02c}Gender_{ic} + \gamma_{03c}BMI_{ic} + \gamma_{04c}Education_{ic} + \gamma_{05c}IndividualLRPolitics_{ic} + u_{0ic} \quad (2)$$

$$\beta_{1ic} = \gamma_{10c} \quad (3)$$

$$\beta_{2ic} = \gamma_{20c} \quad (4)$$

$$\beta_{3ic} = \gamma_{30c} \quad (5)$$

$$\beta_{4ic} = \gamma_{40c} \quad (6)$$

and

$$\gamma_{00c} = \delta_{000} + \delta_{001}FederalLRPolitics_c + v_{00c} \quad (7)$$

$$\gamma_{01c} = \delta_{010} \quad (8)$$

$$\gamma_{02c} = \delta_{020} \quad (9)$$

$$\gamma_{03c} = \delta_{030} \quad (10)$$

$$\gamma_{04c} = \delta_{040} \quad (11)$$

$$\gamma_{05c} = \delta_{050} \quad (12)$$

$$\gamma_{10c} = \delta_{100} + \delta_{101}FederalLRPolitics_c + v_{10c} \quad (13)$$

$$\gamma_{20c} = \delta_{200} \tag{14}$$

$$\gamma_{30c} = \delta_{300} \tag{15}$$

$$\gamma_{40c} = \delta_{400} \tag{16}$$

where the δs are measurement-level intercepts and associations, u_{0ic} are residual unexplained between-person differences that are assumed to be normally distributed with standard deviation σ_{u0}, and v_{00c} and v_{10c} are residual unexplained between-couple differences that are assumed to be independent and normally distributed with standard deviations σ_{v00} and σ_{v10}. To prevent convergence failure, the correlation between random intercept and slope (r_{v00v10}) was not specified. Of specific interest for our research questions are parameters δ_{100}, which indicates the prototypical extent of cortisol synchrony in these older couples, and δ_{101}, which indicates how differences in cortisol synchrony are related to federal-level differences in L-R political context. First, we fit a model (Model A) that examined cortisol synchrony, taking into account all control variables. Second, the federal L-R political context variable was added as a predictor of cortisol synchrony in Equation 13.

All models were estimated using the lme4 package in R (Bates et al., 2015) using restricted maximum likelihood and missing data treated as missing at random. Time since waking was scaled in hours with 0 reflecting wake time. Prior food intake (0 = no prior food intake, 1 = prior food intake), gender (0 = male, 1 = female), and education (0 = no university degree, 1 = university degree) were left uncentered; parameter estimates thus refer to the reference category. Age, body mass index, individual L-R political orientation, and federal L-R political context were centered at the sample mean so that the parameter estimates describe effects for the prototypical older male in the sample.

4.3. Results

Table 4.1 displays descriptive statistics and inter-correlations of central study variables. On a bivariate level, greater cortisol synchrony was linked with a more right-oriented federal level L-R context ($r = .19$, $p < .001$). Older participants had a lower body mass index ($r = –.18$, $p < .001$), more likely had a university degree ($r = .13$, $p = .017$), and reported a more right-wing individual L-R orientation ($r = .19$, $p < .001$). Participants with university degree had a lower body mass index ($r = –.13$, $p = .017$) and higher cortisol levels ($r = .11$, $p = .047$). Male partners were older, $t(159) = 7.1$, $p < .001$, more likely had a university degree ($\chi 2 = 6.1$, $p = .014$), and exhibited greater cortisol levels than their female partners, $t(159) = 2.8$, $p = .005$. There were no significant gender differences in individual L-R political orientation, $t(154) = –0.1$, $p = .920$.

Table 4.1: Means, standard deviations, and intercorrelations of central study variables (N = 320 participants)

Variable	Female Mean (SD)	Male Mean (SD)	2	3	4	5	6	7
1. Age	71.14[a] (5.94)	73.48[a] (5.51)	–.18**	.13*	.05	–.03	.19**	.04
2. Body mass index	26.35 (5.41)	27.41 (4.07)		-.13*	.01	–.03	–.05	–.07
3. Education (1 = university degree)	0.11[a]	0.21[a]			.11*	–.00	.04	.06
4. Log_{10} cortisol	0.63[a] (0.17)	0.67[a] (0.17)				–.05	.04	–.07
5. Cortisol synchrony	0.03 (0.04)						.06	.19**
6. Individual L-R political orientation	4.82 (1.46)	4.84 (1.60)						.06
7. Federal L-R political context	–7.23 (1.49)							

Note. SD = standard deviation. L-R = left-right. * p < .05. ** p < 0.01. [a] Male and female partners significantly differ on these variables.

4.3.1. Cortisol synchrony and federal L-R political context

As can be seen in *Table 4.2*, Model A, the prototypical older couple exhibited cortisol synchrony, as hypothesized (δ_{100} = 0.03, *SE* = 0.01, $p < .001$).[5] There was no significant association between cortisol levels and individual L-R political orientation (δ_{050} = 0.01, *SE* = 0.01, *p* = .689) or federal L-R political context (δ_{001} = –0.01, *SE* = 0.02, *p* = .410). However, as expected, cortisol synchrony was moderated by couples' federal L-R political context (δ_{101} = 0.01, *SE* = 0.00, *p* = .015). As illustrated in *Figure 4-2*, couples showed greater cortisol synchrony if they lived in a federal state that was placed further right on the L-R political spectrum. Cortisol synchrony was not moderated by individual L-R political orientation (*b* = 0.00, *SE* = 0.00, *p* = .502).

The political context variable reduced unexplained variability in cortisol synchrony between couples by 7.5% (Pseudo-R^2) and Model B provided a significantly better fit to the data than Model A ($\chi^2(1)$ = 5.92, *p* = .015). In Model B, the fixed effects explained 57.7% of the overall variance in cortisol and the fixed and random effects together explained 70.3% of the overall variance in cortisol.

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[5] Gender did not significantly moderate cortisol synchrony and the estimated cortisol synchrony coefficient for males and females was identical (δ_{100} = 0.03).

Table 4.2: Results from multilevel models examining cortisol levels (log_{10}nmol/L) using restricted maximum likelihood estimation (N = 160 couples)

	Model A			Model B		
Variable	B (SE)	95% CI	*p*	B (SE)	95% CI	*p*
Fixed Effects						
Intercept, δ_{000}	**2.40 (0.03)**	**[2.34;2.46]**	**<.001**	**2.40 (0.03)**	**[2.36;2.47]**	**<.001**
Time since waking, δ_{200}	**–0.18 (0.00)**	**[–0.19;–0.18]**	**<.001**	**–0.18 (0.00)**	**[–0.19;–0.18]**	**<.001**
Time since waking squared, δ_{300}	**0.00 (0.00)**	**[0.00;0.00]**	**<.001**	**0.00 (0.00)**	**[0.00;0.00]**	**<.001**
Prior food intake, δ_{400}	**–0.05 (0.01)**	**[–0.07;–0.03]**	**<.001**	**–0.05 (0.01)**	**[–0.07;–0.03]**	**<.001**
Age, δ_{010}	0.00 (0.00)	[0.00;0.01]	.305	0.00 (0.00)	[0.00;0.01]	.305
Gender, δ_{020}	**–0.07 (0.03)**	**[–0.14;–0.01]**	**.032**	**–0.07 (0.03)**	**[–0.15;–0.01]**	**.032**
Body mass index, δ_{030}	–0.00 (0.00)	[–0.01;0.01]	.552	–0.00 (0.00)	[–0.01;0.01]	.552
Education, δ_{040}	0.07 (0.06)	[–0.04;0.18]	.227	0.07 (0.06)	[–0.01;0.01]	.227
Individual L-R political orientation, δ_{050}	0.01 (0.01)	[–0.02;0.03]	.689	0.01 (0.01)	[–0.02;0.03]	.689

Federal L-R political context, δ_{001}	–0.01 (0.02)	[–0.04;0.02]	.410	–0.01 (0.02)	[–0.04;0.02]	.410
Partner cortisol deviation, δ_{100}	**0.03 (0.01)**	**[0.02;0.05]**	**<.001**	**0.03 (0.01)**	**[0.02;0.05]**	**<.001**
Partner cortisol deviation x federal L-R political context, δ_{101}				**0.01 (0.00)**	**[0.00;0.02]**	**.015**
Random Effects						
Intercept person, σ_{u0}	0.28					
Intercept couple, σ_{v00}	0.22					
Partner cortisol deviation, σ_{v10}	0.06					
Model Fit						
Deviance	25781.50					
Pseudo R^2	0.70					

Note. B = unstandardized regression coefficient. SE = standard error. CI = confidence interval. L-R = left-right. Gender was coded 0 = male, 1 = female. Education was coded 0 = no university degree, 1 = university degree. Bold font denotes significant regression coefficients. Models are based on 15,232 cortisol values nested within 320 participants. Random effects and fit indicators are from the full model (Model B).

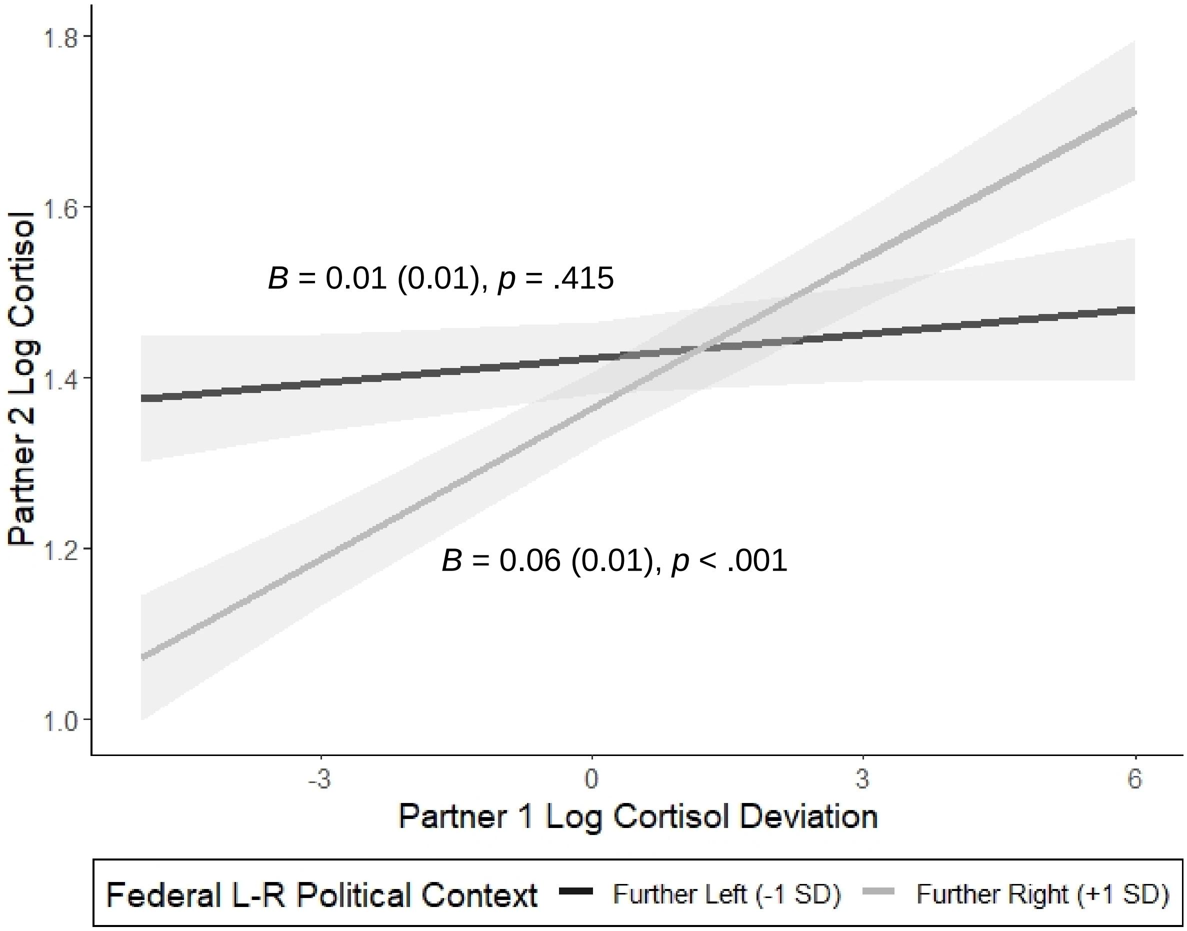

Figure 4-2: Illustration of cortisol synchrony for a federal political context further left (-1 SD) and further right (+1 SD) on the L-R political scale

4.3.2. Follow-up analyses

Although this was not part of what we initially aimed to investigate, we conducted additional follow-up analyses associating cortisol synchrony with other correlates on the federal state level over and above the L-R political context. Specifically, we looked at religiosity, indicators of couple dynamics (divorce, paternity leave), and socio-economic factors (poverty, unemployment). With this, we hope to shed light onto politics-related variables that could play a role for everyday couple dynamics, and to generate ideas for future research. Whereas cortisol synchrony was unrelated to religiosity (percentage of individuals paying church taxes; $b = 0.00$, $SE = 0.01$, $p = .868$), couples showed greater cortisol synchrony in federal states with lower rates of divorce ($b = –0.02$, $SE = 0.01$, $p = .024$), in federal states in which more fathers receive parental allowance ($b = 0.02$, $SE = 0.01$, $p = .005$), in federal states with lower rates of poverty risk ($b = –0.02$, $SE = 0.01$, $p = .016$), and in federal states with lower rates of unemployment ($b = –0.01$, $SE = 0.01$, $p = .029$). Thus, it seems that markers of family values (less divorce, more paternity leave) as well as economic markers (poverty, employment) were related to cortisol synchrony in older couples.

4.4. Discussion

The current study set out to investigate how different political contexts may be associated with everyday psycho-physiological dynamics in older couples. Specifically, we aimed to link the extent to which couples covary in their day-to-day cortisol fluctuations (cortisol synchrony) with their socio-political environment (location of the residential federal state on the L-R political spectrum), controlling for individual's own political orientation. We found that, on average, older couples demonstrated synchrony in concurrent cortisol fluctuations. Furthermore, cortisol synchrony was linked with the federal political context in such a way that couples residing in federal states further right on the political L-R spectrum showed more pronounced cortisol synchrony.

4.4.1. Cortisol synchrony in older couples

Older partners were linked in their everyday cortisol secretion. Thus, in moments when one partner's cortisol was elevated, the other partner's cortisol tended to be elevated, too. This replicates other studies utilizing micro-longitudinal designs and samples across the adult lifespan (Liu et al., 2013; Papp et al., 2013; Pauly, Michalowski, Drewelies et al., 2019). Previous research has demonstrated that cortisol synchrony can neither be described as 'good' nor 'bad', but that its implications need to be seen in context. For example, studies with younger samples have linked greater cortisol synchrony to problematic relationship functioning, such as marital strain and disagreement in young to middle-aged hotel managers and their partners (Liu et al., 2013), partner-aggression in low-income parents (Saxbe et al., 2015), and relationship dissatisfaction in newly married couples (Laws et al., 2015). This line of research emphasizes that cortisol synchrony could be indicative of a maladaptive pattern of escalating each other's stress responses under conditions of high stress or in newly formed units (Levenson & Gottman, 1983). Yet, at the same time, a greater interconnection of cortisol fluctuations may also depict mutual downregulation of physiological arousal, social bonding, and empathic processes (Danyluck & Page-Gould, 2019; Ditzen et al., 2008; Engert et al., 2014). Under conditions of low stress or high relationship satisfaction, cortisol synchrony may thus be indicative of positive relationship functioning (Mercado & Hibel, 2017). We would like to emphasize that the current study took an exploratory approach to test whether couple cortisol dynamics differ by socio-political context, without implying that greater cortisol synchrony is inherently positive or negative.

4.4.2. Cortisol synchrony and left-right political context

We found that the extent to which cortisol synchrony occurs may vary by the socio-political context in which couples live. Specifically, it may be relevant whether they reside in a location that is characterized by more left- or right-oriented politics: Couples living in a German federal state located further right on the L-R political spectrum demonstrated greater synchrony in HPA axis activity in their daily lives. Ratings of the 2017 German election manifestos placed German political parties on a spectrum of –42 (The Left) to +17 (AfD). For comparison, the Manifesto Project rated the Democratic Party as –21 and the Republican Party as +33 for the 2016 US election (Volkens et al., 2019). So far, we know very little to situate daily interpersonal dynamics in their broader socio-political context, to link the macro with the micro. However, findings dovetail with one study examining a similar topic in a younger sample. Schoebi et al. (2010) recruited 623 couples with young children from eight different countries (Austria, Belgium, China, Germany, Netherlands, Portugal, Russia, and Switzerland) for a 7-day micro-longitudinal study. The authors found that interdependence in negative affective states was more pronounced in countries with greater endorsement of collectivistic values (e.g., Portugal, Russia, China) and in couples with higher collectivistic value orientation, regardless of country of origin.

How might the political context get 'under the skin' and translate to everyday couple dynamics in older adults? Transactive goal dynamics theory (Fitzsimons et al., 2015) proposes that interdependence in romantic partners may emerge from (1) the *opportunities* for interdependence and (2) the *motivation* for interdependence. There may be several ways through which the socio-political context may influence *opportunities* for synchrony in older couples. First, politics may determine the wealth and socioeconomic environment of older couples. Follow-up analyses showed that synchrony was greater in federal states with lower rates of poverty and unemployment. Financial security, e.g., through a guaranteed minimum pension, may allow romantic partners to engage in more joint activities and prevent negative interpersonal dynamics that could be elicited by financial strain (W. Park & Kim, 2018). For example, an individual with physical limitations may be able to afford a costly mobility aid, enabling couples to go out together to attend community events or visit friends. Furthermore, more affluent couples may less likely experience stressors that uniquely affect one partner such as one partner having to engage in part-time work, eliciting asynchronous cortisol responses (Chandola et al., 2018). More spending on health care and health services may further preserve intact biological systems in couples and prevent disease-related alterations in HPA axis functioning (Strahler et al., 2017). Intact HPA functioning, in turn, may be associated with a greater propensity to fluctuate with physiological responses of one's significant other, as compared to individuals whose systems have experienced greater wear and tear and are showing signs of dysregulation. Politics also determine the availability and costs of social services (Dykstra, 2018). If physical care can be taken over by professionals, this may leave more room for older partners to provide other, non-instrumental types of support (Brandt et al., 2009; Zarit et al., 1999). Consequently, if a couple is able to employ an external nursing service if need be this may help preserve intimacy and equality, preventing decreases in synchrony that may go along with couple dynamics shifting to a caregiving, rather than a romantic relationship (Chen, 2019, March). Policies promoting aging in place including nursing support, financial aids for home renovations to accommodate functional limitations (e.g., adapted bathtub), or laws requiring new buildings to contain apartments that are fully accessible may also promote autonomy and enable older couples to remain in a shared living environment for longer, thereby facilitating synchrony between partners.

The socio-political context may also shape couples' *motivation* for interdependence. Being located further to the right on the L-R political spectrum tends to be associated with traditional family values and clearly defined gender roles (Caprara & Vecchione, 2018; Thorisdottir et al., 2007). Such a context may provide couples with straight-forward social rules about responsibilities in the relationship, power dynamics, and scripts of expected behaviors. For example, public statements by elected politicians may convey messages about 'suitable' or 'appropriate' structures of romantic interrelations. This could, in turn, contribute to greater daily coordination between partners, less conflict, and thus enhanced synchrony. A greater focus on the importance of family and relationship stability may also contribute to individuals investing more into the couple relationship (Lye & Biblarz, 1993; Schwartz et al., 2010). Greater family values may be linked with greater commitment to one's partner and a greater focus on maintaining positive relationship functioning within the couple relationship in particular, as opposed maintaining positive relationships with other, non-related, network members in general such as friends. This is supported by our follow-up analyses indicating that couple synchrony tends to be greater in those federal states with lower divorce rates and in those in which more fathers receive parental allowance. Finally, a greater emphasis on the family may be conducive to an individual defining themselves partly through the couple relationship (Branand et al., 2019). Such greater self-other overlap could, in turn, foster dyadic synchrony (Galinsky et al., 2005). To sum up, the socio-political context, operationally defined by the L-R political spectrum, may shape everyday physiological dynamics in older couples through laws, policies, and environments promoting or hindering opportunities for synchrony as well as prevalent norms and values underlying differences in motivation for synchrony.

Contrary to the federal L-R political context, individual L-R political orientation was not significantly associated with cortisol synchrony. There may be several explanations for this unique moderation on the contextual level. First, the legislative framework and budget spending decisions with potential implications for couple dynamics are determined by the federal government. Second, social comparison and social desirability biases may have confounded the individual L-R measure (Berinsky, 2004). Two individuals with similar political views may locate themselves on different places on the L-R scale, because their L-R self-judgement may be influenced by comparison of their own political views with dominating political attitudes in their immediate surrounding. Furthermore, individuals were asked to provide the L-R self-rating during an in-person interview. Thus, participants may have less likely endorsed ratings on the extreme left or extreme right end of the scale to conform with socially desirable norms. Using objective data on voting behavior to compute the federal L-R political context score in the current study may have prevented the influence of such self-report biases.

4.4.3. Strengths, limitations, and future directions

Strengths of the current study include (1) combining the macro-level context with micro-social dynamics in older couples, (2) the use of a geographically diverse sample residing in different regions across Germany, (3) the use of cortisol as an objective biomarker of stress, and (4) the assessment of micro-social dynamics in an everyday life context, strengthening ecological validity of findings. However, this methodological approach also comes with the drawback that all findings are correlational, and we thus cannot draw any causal conclusions. The socio-political context may shape couple dynamics, but at the same time couples with certain interpersonal dynamics may also self-select to live in certain contexts. Future research tracking cortisol synchrony over the long-term should investigate changes in synchrony that co-occur with changes in public policies or elected parties. Furthermore, daily life research should be combined with experimental methods to examine mechanisms of the synchrony-political context link. For example, cortisol synchrony could be measured during couple interactions when family values are made salient in a laboratory task. We would expect romantic partners with primed family values to show greater interconnected cortisol fluctuations during an interaction task such as sharing a personal concern, as compared with couples who received no such priming.

Couples in the current study had to have completed SOEP questionnaires for at least three previous years. Thus, this sample is comprised of older couples who were committed to contribute to a time-intensive longitudinal study. They further had relatively high relationship satisfaction and had been with their partner for an average of 47 years (minimum 4 years). We therefore cannot know if findings generalize to older couples in new relationships and to those with lower relationship quality. Additionally, there have been tremendous shifts in gender dynamics and family structures over the past decades, with a rise in non-traditional family forms, increases in female workforce participation, and the reduction of gender-stereotyped expectations (Settersten, 2018). Consequently, we do not know if the present findings will generalize to the generation growing up in such changed societal conditions, i.e. to future cohorts of older couples.

We focused on one commonly-used indicator of political ideology (the L-R political spectrum) and examined its association with daily life linkage in one marker with relevance to health (cortisol). All German federal states were located on the left side of the L-R spectrum. Thus, it remains to be determined how a political context above 0 on the L-R scale may be linked with everyday couple dynamics. Extending the current findings, couple synchrony should also be investigated with respect to other indicators of the broader socio-political context, including individualistic/collectivistic values and predominant conceptions of romantic relationships. For example one could compare cortisol synchrony of couples in countries in which unit-formation is based on romantic love as compared with arranged marriages (Randall et al., 2011). Finally, it remains to be determined whether synchrony in other, non-physiological, indicators such as affect and behavior would be greater in couples living in a context further right on the L-R scale.

4.4.4. Conclusions

The larger macro-context in which smaller social units such as couples live may shape the nature of daily interpersonal dynamics. The current study aimed to situate the extent to which older romantic partners are linked in their everyday life fluctuations in the stress hormone cortisol (cortisol synchrony) to the socio-political context. Specifically, we found that cortisol synchrony was more pronounced in couples who lived in a federal state located further right on the L-R political spectrum. The political context may shape couple dynamics through creating opportunities for interdependence in romantic partners, and through influencing motivations for such interdependence. Failing to consider the macro-context and upstream factors when looking at the link between social relationships and health carries the risk of neglecting important factors that contribute to such dynamics.

Chapter 5: General discussion

5.1. Synthesis

The concept of synchrony is proposed to be at the core of living organisms, and human existence. From fireflies flashing in sync at millisecond precision to individuals unintentionally matching their behaviour to others around them, such as clapping at the same rhythm, walking at the same gait, or rocking in the same pattern in a rocking chair (Janney et al., 2014; Moiseff & Copeland, 2010; Néda et al., 2000; Nessler & Gilliland, 2009). The current thesis investigated this phenomenon in the context of everyday physiological dynamics in older couples. Specifically, it focused on synchrony in daily fluctuations of cortisol, which is a prominent marker of physiological arousal and particularly sensitive to social input (Dickerson & Kemeny, 2004; Kirschbaum et al., 1995). Significant linkages in fluctuations of cortisol levels were found across three different samples of older adult couples (Chapters 2 through 4). This means that if one partner displayed cortisol levels that were elevated or decreased in comparison with their typical cortisol level for that time of day, their partner was more likely to display elevated or decreased cortisol levels, too.

Building on the developmental-contextual model of dyadic synchrony (Pauly et al., under review), Chapters 2 through 4 aimed to better understand contextual correlates of cortisol synchrony, individual differences therein, and potential long-term consequences. The purpose of Chapter 2 was to illuminate daily life situations (proximal contexts), in which cortisol synchrony might be more or less pronounced. I further linked cortisol synchrony with one pertinent individual difference characteristic: self-reported empathy. I found support for cortisol synchrony being higher when partners were present, and when partner interactions involved feeling understood and appreciated and seeking help or closeness. Partner interaction-synchrony associations were stronger in younger as compared with older participants. Furthermore, participants higher in perspective-taking tended to exhibit greater cortisol synchrony with their partner. Thus, findings highlight that social bonding and the ability to understand one's partner's thoughts and feelings are intertwined with physiological synchrony in everyday life.

Next, Chapter 3 set out to better understand implications of cortisol synchrony in older couples, by investigating potential long-term risks and benefits associated with being 'in sync'. As detailed in my developmental-contextual model of dyadic synchrony (Pauly et al., under review), daily processes were thought to accumulate over time, with important ramifications for individual and couple functioning in the long run. Utilizing a data set which followed older couples over a 3-year period, I found that higher cortisol synchrony was associated with a stronger increase in relationship satisfaction but also a stronger increase in non-HDL cholesterol levels over time among wives. For husbands, higher cortisol synchrony was not significantly associated with changes in relationship satisfaction or non-HDL cholesterol levels over time, but it was associated with higher initial non-HDL cholesterol levels. This indicates that cortisol synchrony could play a role for positive relationship functioning and relationship maintenance, particularly among women. However, being strongly linked to a romantic partner's physiology may also come with the cost of experiencing negative health outcomes long-term in the context of repeated transmission of stress responses.

Besides placing dyadic synchrony within its proximal daily context and considering the interconnection with long-term outcomes, the developmental-contextual model of dyadic synchrony also emphasizes the importance of taking couples' macro context into account (Pauly et al., under review). Broader socio-contextual features of couples' environment may influence opportunities and motivation for synchrony in older romantic partners. In Chapter 4, I examined links between cortisol synchrony and the socio-political context utilizing a sample of German older couples, residing in 13 different German federal states. Specifically, I examined whether cortisol synchrony may differ based on how far left or right couples' federal state of residence is placed on the L-R political ideological spectrum. I found that the degree of cortisol synchrony was moderated by macro-context, such that couples living in a federal state further right on the L-R political spectrum exhibited greater cortisol synchrony.

Together, findings highlight that cortisol synchrony in older couples needs to be seen in context; both at the micro-level by looking at proximal contexts such as partner presence or partner interactions and at the macro-level by looking at distal contexts such as public policies and laws (e.g. regulations around retirement and pension) and prevalent norms and values (e.g. expectations about couple dynamics). In addition, person-characteristics (e.g. the ability to take someone else's perspective) may be intertwined with cortisol synchrony in older partners. Findings further point to the importance of not just analysing *contexts* on a micro- and macro-level, but also integrating micro and macro *time*. Particularly, I showed that micro-social dynamics observed in daily life may be intertwined with longer-term trajectories of health and relationship functioning (Chapter 3). In the introductory chapter of this thesis (Chapter 1), I explained that I chose the term 'synchrony' to describe the phenomenon under study partly because this term is value neutral. Chapter 3 underlines that, indeed, synchrony can neither be seen as good nor bad. Similarly to the double-edged nature of empathy (Dekel et al., 2018; Manczak et al., 2016; Russell & Brickell, 2015), synchrony may have positive interpersonal connotations while at the same time putting individuals at health risk.

5.2. Strengths, limitations, and future directions

5.2.1. Operational and statistical approaches to measuring couple synchrony

Although there are only a limited number of studies on physiological synchrony in romantic partners, a systematic review on parent-child dyads found the strongest evidence for synchrony in markers of adrenocortical functioning (such as cortisol), as compared with markers of the parasympathetic system (such as respiratory sinus arrhythmia), markers of the sympathetic system (such as electrodermal activity), or mixed parasympathetic/sympathetic markers (such as heart rate; Molly Davis et al., 2018). Thus, markers of HPA axis activity present a promising target for the study of everyday psychosocial dynamics in older couples.

As another strength of the current work, cortisol dynamics have direct implications for partners' well-being, because there is a broad evidence base linking increased cortisol levels to mental and physical health risk (Adam et al., 2017). Furthermore, self-reported and objectively measured stress responses do not necessarily correspond in daily life or the laboratory (Dickerson & Kemeny, 2004; Hjortskov et al., 2004). There is initial evidence that this divergence may be stronger in older adults: While negative affect reactivity stays consistent or decreases with age, blood pressure reactivity may increase (Koffer & Kamarck, 2019; Uchino et al., 2006). Thus, the use of an objective marker tied to health risk seems to be particularly important in old age.

However, as a limitation to using a physiological marker, I cannot assume that connected cortisol fluctuations in couples necessarily imply similar psychological states or that they were caused by the same external event (Thorson et al., 2018). Future studies need to supplement objective markers of synchrony with momentary measures of thoughts (e.g. trying to understand the partner's perspective), motivations (e.g. motivation to attend to the partner), external events (e.g. joint and individual stressors), and behaviours (e.g. visual attention on the partner).

Researchers have used different statistical approaches to quantify couple synchrony, including multilevel models, dynamical correlations, and coupled-oscillator models (Helm et al., 2012; Liu et al., 2016; Thorson et al., 2018). I have chosen a multi-level approach for the following reasons: 1) Multi-level models can easily handle missing data and unbalanced data designs (i.e. a different number of observations for each couple); 2) as compared with dynamical correlations, they allow to model predictors at different levels of analysis (e.g. associations of synchrony with momentary contexts or individual/couple characteristics); and 3) they allow to extract synchrony estimates (random effects) on the couple level, in order to use them as predictors in subsequent models, as done in Chapter 4. In contrast to multi-level models, coupled-oscillator models come with the advantage of being able to examine temporal dynamics such as dampening or amplification of physiological fluctuations, allowing researchers to investigate whether couples can help each other return to a shared level of homeostasis, or if they amplify each other's states away from a shared baseline (Butler & Barnard, 2019; Helm et al., 2012). Yet, such models may be more applicable to physiological measures which demonstrate oscillatory patterns, including heart rate and respiration (Helm et al., 2012). I did not find any significant linkages in cortisol levels in random partner pairings, which mitigates the concern that the detected synchrony could be an artifact of the chosen method (LL project random synchrony coefficient: $b = 0.006$, $SE = 0.021$, $p = .788$; BCS project random synchrony coefficient: $b = 0.007$, $SE = 0.008$, $p = .379$; ELOC project random synchrony coefficient: $b = 0.005$, $SE = 0.005$, $p = .263$). Future research is needed to examine whether findings of the current thesis replicate across different statistical approaches, and utilizing other physiological markers.

5.2.2. Community samples

The current thesis utilized three different data sets of community-dwelling older adults. As a strength of the present work, I showed that the phenomenon of cortisol synchrony is present in samples of varying ethnic backgrounds, geographic locations (Canada, Germany), and across a considerable age-range (56 to 89 years). Participants reported fairly good self-rated health and relatively high relationship satisfaction, on average. With older age, individuals tend to report fewer daily stressors, less conflict, and more positive daily social interactions (Luong et al., 2011; Stawski et al., 2008). Thus, the high reported levels of relationship satisfaction in the current samples reflect a known phenomenon of relationship dynamics in old age. Previous research with younger to middle-aged couples has shown that cortisol synchrony can sometimes be indicative of negative relationship dynamics if it means that partners escalate each other’s arousal during interpersonal conflict or in other stressful everyday contexts (Laws et al., 2015; Liu et al., 2013; Saxbe et al., 2015). Future studies should build on the current thesis by examining cortisol synchrony in older couples reporting high relationship conflict and a greater amount of negative daily social interactions to address generalizability and boundary conditions. I suspect that synchrony may show a less pronounced association with indicators of positive relationship dynamics in these samples.

Volunteer samples tend to be healthier than the general population, a bias that increases with older age (Ganguli et al., 1998; Golomb et al., 2012). Future studies should consider cortisol synchrony in relation to declining health, decreases in cognitive functioning, and visual impairments. Declining cognitive abilities and vision impairment may interfere with an individual's ability to accurately detect their partner's mental states (Hülür et al., 2016; Strawbridge et al., 2007), which may be linked with less physiological transmission from one partner to the other. Supporting this proposition, a recent study demonstrated that physiological synchrony was decreased in individuals with dementia, as compared to healthy control dyads (Chen, 2019, March). Health limitations may further require the use of services such as adult day care or a relocation to a residential care facility, resulting in the physical separation of couples (Zarit & Reamy, 2013). Less time spent in physical proximity may, in turn, contribute to diminished synchrony. To sum up, the use of three different community-dwelling samples can be seen as a strength of the current thesis, but research is needed to evaluate generalizability of findings to older couples with higher relationship conflict and to those with significant physical and cognitive limitations.

5.2.3. Daily life assessments

The current study took a daily life approach, collecting information about psychosocial processes, and their physiological correlates in older couples' natural environment. Across studies, participants reported that their participation period was typical for their daily lives (*M* = 3.6 to 4.1 out of 5, from 1 = "not at all typical" to 5 = "very typical"), pointing to the fact that the recorded data captured their usual routines. Participants also reported that they did not significantly change their behaviour in response to the study protocol (LL project: *M* = 1.77; BCD project: *M* = 1.84; ELOC project: *M* = 1.82; from 1 = "not at all" to 5 "very much"). As instructed, participants completed the assessments at roughly the same time as their partner, on average. For the morning questionnaires, 59%, 78%, and 71% were completed within 30 minutes for the LL, BCD, and ELOC projects. For the day questionnaires, the respective numbers were 92%, 97%, and 88%.

5.2.3.1. Observing life as it is lived

A major strength of the daily life approach is that it lessens concerns about recall biases associated with retrospective self-reports (Smyth et al., 2017). This may be particularly important in the case of older adults because of an age-normative positive skew of appraising and rating social experiences and social relationships and in the light of age-normative cognitive decline including memory problems (Hoppmann & Riediger, 2009; Luong et al., 2011). For example, older partners tend to rate their spouse's behaviour during conflict as more positive than independent observers, whereas middle-aged couples show no such bias (Story et al., 2007). Furthermore, it allows to observe natural social interactions in individuals' daily lives, paying tribute to couple's unique interpersonal dynamics (Smyth et al., 2017). Thus, this approach complements literature using standardized laboratory interaction tasks (e.g. Ditzen et al., 2009; Kiecolt-Glaser et al., 2005) by collecting data on the nature and frequency of older couples' idiosyncratic relationship contexts.

Previous research has highlighted that the daily life approach can be of particular value when trying to establish relationships between momentary psychosocial contexts and concurrent physiological processes (Conner & Barrett, 2012). In their review of daily life and retrospective self-report techniques, Conner and Barrett (2012) suggest that these reports are influenced by different types of self: The 'experiencing' self provides the foundation for assessments in the moment, whereas the 'remembering' and 'believing' selves inform retrospective reports and trait measurements. The authors conclude that momentary assessments in daily life are thus expected to show stronger ties with physiological stress markers, as compared with retrospective self-report measures. Studies collecting data on cardiovascular reactivity as well as HPA axis activity provide empirical support for this notion (Kamarck et al., 2005; Steptoe et al., 2007). However, there are also important limitations to the daily life approach that warrant mentioning.

5.2.3.2. Correlation vs. causation

A central caveat is that data are correlational and cannot speak to any causal mechanisms. Thus, I cannot infer whether cortisol synchrony is the product of interpersonal processes, or whether it can partly be attributed to shared contexts or to individuals reacting the same way to external events due to similar personalities (assortative mating; Luo, 2017). In follow-up analyses, I did not find any significant associations between aggregate scores for couples' shared activities or shared locations and cortisol synchrony (see Appendix C). I take this as initial evidence for the notion that interpersonal interactions may be important and may trump shared contexts in everyday life. Future studies using experimental designs are needed to examine potential mediating pathways.

One candidate related to both HPA axis functioning and social processes may be oxytocin (Cardoso et al., 2014; Heinrichs et al., 2003; Neumann, 2002). Oxytocin has been shown to facilitate processing of social cues and to enhance accuracy of affect ratings (Guastella et al., 2012). In line with this idea, a recent study demonstrated that higher oxytocin levels were associated with greater interactive reciprocity in young newly-formed couples, as demonstrated by gaze synchrony, positive affect, interpersonal focus, matched emotional states, and affectionate touch (Schneiderman et al., 2012). Synchrony may also emerge via increased oxytocin levels attenuating HPA axis activity in both partners, following positive couple interactions. A laboratory study that builds on the current thesis could measure physiological synchrony in couples randomized to nasal oxytocin administration vs. a placebo nasal spray to investigate this pathway (Weisman et al., 2012). Furthermore, future studies ought to address to what extent synchrony in cortisol fluctuations may be caused by psychological processes (e.g. through an empathic response to stressors affecting one's partner; Engert et al., 2014) or by subconscious biological processes (e.g. through hormones or olfactory cues; Wyart et al., 2007). For example, one could compare cortisol synchrony in couples during an interaction task with couples interacting through electronic text (purely psychological cues), over the phone (auditory cues), video chat (visual and auditory cues), or in person (visual, auditory, and olfactory cues).

Links between cortisol synchrony and health as well as relationship processes might also be reciprocal. On the one hand, repeated transmission of stress responses may result in increased health risks associated with chronic stress exposure, as indicated by the link between cortisol synchrony and non-HDL cholesterol levels. On the other hand, I found that associations between positive socio-emotional partner interactions and cortisol synchrony were less strong in old age (Chapter 2). This could be explained by accumulated wear-and-tear making older adults' physiological systems less responsive to environmental cues (Charles, 2010; McEwen & Seeman, 1999). Decreased physiological flexibility could, in turn, lead to a diminished capability of biological systems to synchronize with a partner's physiological states (Thorson et al., 2018). Along the same vein, synchrony may contribute to and be shaped by relationship functioning. For instance, greater cortisol synchrony may result in higher relationship quality through its connection with social bonding processes (Mercado & Hibel, 2017). At the same time, greater relationship quality may contribute to increased closeness or more time spent together and, consequently, more connected cortisol fluctuations (Timmons et al., 2015). Utilizing longitudinal data on physical activity synchrony and relationship satisfaction from the LL project, I was able to show that greater synchrony in moderate-to-vigorous physical activity and sedentary behavior at T1 were related to greater relationship satisfaction one year later (T2), whereas T1 relationship satisfaction did not predict T2 physical activity synchrony, controlling for autoregressive effects (Pauly et al., 2019, September). Thus, I have initial evidence that synchrony in daily lifestyle behaviours might be a predictor, rather than an outcome of relationship functioning. Future research needs to investigate whether these findings translate to cortisol synchrony.

5.2.3.3. Daily protocol design

When designing daily diary protocols, the researcher has to choose between collecting more intense measurements over a shorter period of time or less intense measurements over a longer duration, so the total amount results in reasonable participant burden. The projects included in the current thesis collected salivary cortisol samples 5-7 times per day over a period of 7 days. This is in line with recommendations to prioritize collecting fewer cortisol samples over more days to accurately detect within-person changes (Segerstrom et al., 2014). However, this decision also came with the disadvantage that cortisol measurements were spaced too far apart (approximately 3 hrs for the BCS and ELOC projects to 5 hrs for the LL project) to be able to investigate direction of transmission of physiological stress responses between partners. Future studies could extend the current findings by collecting data on everyday physiological synchrony utilizing biomarkers which can be measured continuously or in shorter time intervals without adding participant burden including ambulatory blood pressure, skin conductance, or heart rate (Conner & Mehl, 2015; Helm et al., 2018). This may help answer questions such as whether power dynamics in the relationship may relate to which partner drives synchronization of physiological states or whether the influence is mutual (Timmons et al., 2015).

5.2.4. Cortisol synchrony: Considerations of validity and reliability

As compared with controlled laboratory conditions, there may be multiple factors influencing HPA axis activity in daily life, including chronic diseases, medications, and momentary activities participants engage in briefly before saliva collection (Hoppmann et al., 2016; Kudielka et al., 2012; Strahler et al., 2017). I took a number of measures to try to limit the influence of these confounding variables. First, individuals with chronic conditions related to altered HPA axis functioning (e.g. thyroid dysfunction) were excluded. Second, cortisol profiles of all individuals were visually inspected and participants with aberrant profiles who also reported taking medications influencing HPA axis activity were removed from analyses. Third, the projects included in the current thesis asked participants to record at each assessment point whether they had engaged in activities linked to cortisol secretion including brushing teeth, showering, sleep, physical activity, eating, smoking, taking medication/drugs, and consuming alcohol or caffeine prior to saliva collection. I empirically tested whether any of these momentary confounders showed links with cortisol levels and retained significant variables as covariates for model parsimony. Participants' non-adherence to the saliva collection protocol may further threaten internal validity of findings. Yet, participants of the current studies completed 91% (LL project) to 98% (BCD and ELOC projects) of scheduled cortisol assessments, indicating good adherence. Electronic questionnaires also asked participants to report which sample number they used for saliva collection, and information on accidentally swapped samples as well as feedback gathered during the in-person exit sessions were used for data cleaning purposes.

A further limitation is that I do not know to what extent cortisol synchrony is situation specific or a couple-level characteristic. A premise of the current line of research is that cortisol synchrony, as measured via connected cortisol fluctuations, is a valid indicator of couple level dynamics and can, to at least some extent, characterize differences between couples. Studies have demonstrated that synchrony can be more pronounced in some momentary contexts and less pronounced in other contexts (e.g., talking about relationship concerns vs. talking about events of the day; Chaspari et al., 2015). I corroborate these findings by demonstrating that cortisol synchrony varies moment-to-moment with partner presence and positive partner interactions. This speaks to the situation-specificity of cortisol synchrony. However, there is also indication that some variation in cortisol synchrony can be found on the couple level. Follow-up analyses utilizing procedures as outlined in Neubauer et al. (2019) indicated that reliability of cortisol couplings was moderate across the three studies (LL project mean coupling-reliability = 0.40, *SD* = 0.05; BCS project mean coupling-reliability = 0.58, *SD* = 0.03; ELOC project mean coupling-reliability = 0.53, *SD* = 0.01). Additionally, I demonstrated that not just cortisol levels but also levels of moderate-to-vigorous physical activity and sedentary behavior are synchronized in older couples, utilizing the LL project (Pauly et al., 2020). Thus, there seems to be a shared underlying construct driving interconnected psychophysiological states in older partners.

The studies in the present manuscript assessed cortisol over 7 days, based on previous recommendations on detecting within-person fluctuations (Segerstrom et al., 2014). Yet, future research needs to investigate how many observations are needed to accurately characterize the 'synchrony score' of a couple (e.g. how many days are needed, across how many and which situations does cortisol synchrony need to be measured). Adding to the notion of predictive validity, I was able to use couples' cortisol synchrony scores to predict levels of and changes in relevant indicators of health risk and relationship functioning over time. However, to discover to what extent synchrony is a stable attribute of a given couple, to what extent it is situation-specific, or to what extent it is driven by couple-situation interactions (i.e., certain couples showing synchrony during certain situations and not in others), future research needs to assess cortisol synchrony repeatedly over longer time intervals, for example in two measurement bursts three months apart (Sliwinski, 2008).

It also remains to be determined if synchrony is domain general or domain specific. Empirical evidence on this topic is sparse and mixed. One study found that young to middle-aged women who demonstrated higher physiological linkage to their partner in the laboratory also demonstrated higher partner linkage in affect in daily life (e.g. Ferrer & Helm, 2013). In contrast, another study reported that physiological synchrony was unrelated to affect reciprocity (e.g. Levenson & Gottman, 1983). If couple synchrony translated across different psychological, biological, and behavioural indicators in older adults, this would add further evidence to synchrony being a relevant phenomenon to index couple characteristics which are key to understanding individual and couple outcomes.

5.2.5. Effect sizes and power

Overall explained variance of models ranged from 38% to 74% (Pseudo-R^2; Nakagawa et al., 2017). Introducing predictors of interest to the models reduced unexplained variability in the respective outcomes by 5% to 20% (Δ Pseudo-R^2). The magnitude of these effects dovetails with effect sizes reported in other daily life research with older adults (Katana et al., 2020; Pauly, Lay et al., 2019; Robins et al., 2018). Whereas the researcher has close control over confounding variables in the laboratory, cortisol levels are multiply determined in everyday life (Hoppmann et al., 2016). Necessarily, predictors of interest tend to explain smaller amounts of variance in a field context than in the lab (Bolger et al., 2003; Maner, 2016). However, I believe that findings nonetheless possess practical relevance because small effects which happen repeatedly over time in an everyday context may ultimately accumulate to impact health outcomes in the long run.

With regards to power in multilevel models, Maas & Hox (2005) recommend a sample size of at least 50 units on the upper level. All data sets included in this thesis meet this minimum requirement (77 to 160 couples). Yet, power in multilevel models is not just influenced by sample size but also by the specified variance-covariance structure of random effects. Specifically, models that are more complex, for example those that specify random slopes, carry the risk of being over-conservative when the number of upper level units is small (Matuschek et al., 2017). I decided to model the random slope for cortisol synchrony for two reasons: 1) From a conceptual perspective I expected cortisol synchrony to differ between couples and 2) Inclusion of the random slope significantly improved model fit. Limited power in these more complex models may explain why the association between self-reported perspective taking and cortisol synchrony did not reach levels of conventional significance (p = .065, see Chapter 2.3). Notably, the respective association was significant in models including random intercepts, but omitting random slopes. Consequently, the reported findings are from multi-level models with potentially more conservative testing.

Required sample sizes for structural equation models can range from 30 to 460, depending on the number of indicators for each factor, the number of factors, the specified intercorrelations, and missing data (Wolf et al., 2013). The sample size for the dyadic growth curve structural equation models reported in Chapter 3 (N = 85 couples) is in line with other couple studies using similar methods (Goldberg & Smith, 2011; Ha et al., 2012; Kilpatrick et al., 2002). However, I cannot rule out the alternative explanation that limited power may have contributed to non-significant findings in Chapter 3, and to differences in associations of cortisol synchrony with outcomes of interest between men and women.

5.3. Extending the scope

In the following section, I would like to outline how this line of research could be extended to the consideration of 1) other social units, 2) other areas of functioning, and 3) changes in ontogenetic and historical time.

Romantic partners represent a common social unit that serves as the most central relationship for a large number of older adults (Hoppmann & Gerstorf, 2016; Slatcher & Selcuk, 2017). However, the interpersonal processes described in this thesis should be investigated in *all types of romantic pair bonds*. Interpersonal dynamics with ramifications for health and gendered relationship patterns may differ by union type (Umberson & Thomeer, 2020). In fact, health concordance may be greater in same-sex as compared with different-sex couples (Holway et al., 2018). There is a succinct lack of research on aging couples with non-normative gender or sexuality, in particular (Michalowski et al., 2016; Umberson et al., 2015). Synchrony may also develop between *other dyads*, including strangers, teammates, or singers in a choir (Cwir et al., 2011; Mønster et al., 2016; Müller & Lindenberger, 2011). For individuals working in teams, including paramedics and police officers, synchrony may be particularly important for optimal work performance in critical situations (Power, 2018). Very few studies have directly compared the nature and correlates of synchrony between romantic partners and other social units (e.g. Engert et al., 2014; Kinreich et al., 2017). One study has demonstrated that the heart rate of individuals who were walking over hot coals synchronized with their friend or relative who was watching, but not with unrelated spectators (Konvalinka et al., 2011). Future research should investigate what types of synchrony may be couple specific or are more pronounced among romantic partners.

Over and above the health of both partners, cortisol synchrony may also have important implications for other *domains of functioning*, including cognition and individual well-being. A laboratory study showed that synchronized movements can enhance memory for a social interaction (Macrae et al., 2008). Synchrony could also facilitate effective cooperation in couples, allowing them to more successfully complete daily cognitive tasks such as managing finances (Miles et al., 2017; Wiltermuth & Heath, 2009). Furthermore, couples who are ‘in sync’ may have greater insight into each other’s goals, which could be linked with promoting each other’s goal pursuit and progress (Hoppmann & Gerstorf, 2013). Other studies have linked behavioural or affective synchrony with self-esteem (Lumsden et al., 2014), increased pain threshold (Lang et al., 2017), life satisfaction (Sels et al., 2016), and positive affect (Mogan et al., 2017). It remains to be determined whether these positive implications may translate to physiological synchrony in older couples in general, and cortisol synchrony in particular.

Cortisol synchrony should not just be considered in the context of other social units and other individual and dyad outcomes, but also in the context of progressing *historical* and *ontogenetic time* (Pauly et al., under review). For example, the emerging and increasing use of technology for social communication has elicited substantial shifts in the quantity and quality of interpersonal interactions. A decade ago, when partners were physically separated (e.g., during the workday or if one partner was travelling) they had fewer opportunities to stay ‘in-touch’ and ‘up-to-date’ with each other’s current experiences. Nowadays, smartphones enable couples to check in with their partner frequently throughout the day. Time use diary data of representative samples surveyed in 1965, 1975, 2003, and 2012 further showed that more recent cohorts tend to spend more time with their partner, due to an increase in shared activities (Genadek et al., 2016). Thus, one could assume that everyday synchrony would be higher in younger cohorts.

Couple synchrony may also change with progressing ontogenetic time and relationship duration. In the developmental-contextual model of dyadic synchrony, I propose that synchrony exhibits a u-shaped trajectory across adulthood, with greater synchrony in younger and in older couples, but with a dip in very old age (Pauly et al., under review). Furthermore, age-normative or non-normative life events that individuals encounter such as accidents, retirement, or grandparenthood can elicit substantial change in daily routines with ramifications for couple dynamics (Neugarten, 1968, 1979). These life events can challenge the couple as an interconnected system, and have the potential to increase as well as decrease physiological synchrony. Measurement burst designs, which collect bursts of daily assessments repeatedly over a longer period of time, or shortly before and after an important life event, are necessary to shed light on systematic temporal changes in couple synchrony.

5.4. Implications

This line of research emphasizes that romantic partners are deeply intertwined in everyday processes relevant for health, i.e. fluctuations in the stress hormone cortisol. Yet, research on lifespan development and health systematically fails to consider this fundamental social context of an individual’s functioning. Notably, studies demonstrate that work disability clusters in couples (Saarela et al., 2019; Vie et al., 2013). For example, if one partner receives sickness allowance or disability pension, their partner’s risk of receiving the same benefit in the following years increases by 50% to over 100% (Saarela et al., 2019). This close interconnection has at least two implications. First, health interventions targeted at changing an individual’s health behaviour may need to consider bringing close social others on board as well (Arden-Close & McGrath, 2017). One may imagine that an intervention aiming to reduce stress in one individual may not be successful, if it fails to consider that their partners’ stressors affect them just as much as their own stressors (i.e. that they elicit synchronous reactions in physiological arousal in both partners). Second, if one partner falls ill, close attention should be paid to the functioning of the other partner, as they may share a life history of similar risk factors including health behaviours and accumulated physiological vulnerabilities. For example, primary care providers may want to screen partners of individuals who present with a cardiovascular event for their own chronic disease risk and subsequently include them into planning treatment (Litzelman et al., 2016). A high synchrony in physiology may point to the kind of couples, for which such considerations are especially important.

Furthermore, cortisol synchrony could be utilized to indicate adaptive vs. maladaptive relationship functioning. The current thesis investigated cortisol synchrony on a continuous spectrum, examining conditions under which synchrony may be less or more pronounced. Yet, there may also be a threshold of synchrony that is needed to maintain positive relationship functioning, and this threshold may differ across different life phases (Gonzaga et al., 2007). Based on behavioural and physiological measures collected during a brief couple interaction in the laboratory, Gottman et al. (1998) were able to predict divorce and relationship satisfaction among 130 newly-wed couples who were followed over a 6-year period with 83% and 80% accuracy. Future research needs to address if information about cortisol synchrony can be used in a similar way, and whether the maintenance of a minimum amount of synchrony is necessary to prevent relationship dissolution. Based on this line of research, one could identify targets for interventions on couple functioning (Timmons et al., 2015). There are some intervention studies aimed at enhancing synchrony between children and their caregivers, particularly in the context of autism spectrum disorder (Bernard et al., 2013; Landa et al., 2011). Similar to these programs, synchrony interventions with couples could aim at promoting expression of internal states to the partner, correct perceptions of internal states of the partner, and identifying opportunities for synchronous interactions in daily life. Considering the lack of empirical data, such propositions about the implications of cortisol synchrony in older couples are purely speculative and need to be corroborated by future research. Particularly, they are based on the assumption that cortisol synchrony reflects positive relationship dynamics (as demonstrated in the samples in the current thesis). Yet, research on negative reciprocity indicates that stronger linkage may be maladaptive under certain circumstances, promoting mutual escalation of negative interpersonal dynamics (Escudero et al., 1997; Levenson et al., 1994; Margolin, 1981). Whether this also applies to cortisol synchrony in older couples remains to be determined.

5.5. Conclusions

Close relationships, including the relationship with a significant other, have a major impact on an individual’s health and well-being (Seeman, 1996). Synchrony, as defined by the interdependence of temporal fluctuations in psychobiological states of at least two individuals, has long been recognized as an important characteristic for the caregiver-child relationship (see reviews by Molly Davis et al., 2018; Harrist & Waugh, 2002; Leclère et al., 2014). Impaired mother-child synchrony has been connected to psychopathology in the mother as well as the child (Molly Davis et al., 2018; Leclère et al., 2014) and there is a well-established link between caregiver-child synchrony and positive social, cognitive, and behavioural child development (Harrist & Waugh, 2002; Leclère et al., 2014). My dissertation suggests that this phenomenon does not cease being a crucial indicator for relationship dynamics and translates to romantic relationships in old age. Specifically, it may be one physiological pathway through which older romantic partners shape each other’s health trajectories. A better understanding of how physiological stress responses are linked in everyday life, and what adaptive and maladaptive implications this may have for individual aging dynamics may help guide future interventions to improve health and well-being. The present thesis aimed to identify proximal contexts (partner presence, partner interactions), distal contexts (socio-political context), and individual characteristics (empathy) that need to be taken into account. It further points to potential long-term ramifications of cortisol synchrony for individual and couple functioning (cardiovascular risk, relationship satisfaction). I hope findings will inspire future research on micro-social dynamics, to better understand how relationship partners can get ‘under our skin’ in our daily lives.

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Appendices

Appendix A. Details and extended descriptives for the LL and BCD projects

Data from the LL sample stem from a larger project on spousal health dynamics in old age. This larger project examined the role of relationship-, individual-, and situation-specific factors for shaping stress and physical activity in daily life as well as longer-term outcomes. Community-dwelling couples aged 60 years and above provided repeated daily life assessments and they completed annual follow ups. Each couple participated in a 3-hour baseline session, 7 days of repeated daily life assessments, an exit session, and was invited to take part in annual follow-ups for the subsequent 2 years. Repeated daily life assessments and saliva samples were only provided in year 1.

Couples provided basic demographic information and they completed health and cognitive measures. They also provided information regarding social and personality variables and subjective well-being. Repeated daily life assessments (5 measurement points/day) were completed on iPads using a senior-friendly survey app (iDialogpad; G. Mutz, Cologne, Germany). Physical activity was measured using accelerometers (Actigraph), saliva samples were collected using Salivettes (Sarstedt, Germany; at waking, 30 min after waking, 11 AM, 4 PM, 9 PM), and blood draws were conducted at a commercial laboratory (Lifelabs). Participants were reimbursed $100 CAD for their participation in Year 1. Participants were contacted again for the following 2 years and asked to complete the same measures administered in Year 1 (excluding the repeated daily life assessments and saliva samples). Spouses were able to participate together or alone and they were reimbursed $50 CAD for each annual follow-up assessment they completed.

From an original sample of 129 older couples entering the study, nine couples dropped out after the baseline session. Data from one couple were excluded due to limited command of the study language and 34 couples were excluded due to missing data on key study variables: Two couples were missing cortisol data and 28 couples were not asked to provide saliva samples due to conditions that impact the interpretation of cortisol values, e.g. thyroid dysfunction; data of four additional couples were excluded due to abnormal cortisol profiles and taking medications influencing HPA axis activity such as glucocorticoids or medications for anxiety, depression, or psychosis. The 170 retained participants (85 couples) did not differ from excluded participants in terms of age, self-rated health, body mass index, ethnicity, education, or retirement status. *Table A-1* displays further sample characteristics.

Data for the BCD project were collected as part of a study on the everyday life of older couples in Berlin, Germany. Participants were recruited via announcements in local Berlin newspapers. At initial telephone contact, participants were screened according to the following criteria: First, participants had to be aged 70 years or older; or, if only one partner was 70 years or older, the younger partner had to be older than 65 years. Second, both partners had to live in the same household. Third, participants had to have sufficient command of the German language. Fourth, participants' corrected vision had to be sufficient to read small newspaper titles and their corrected hearing had to be sufficient to hear the door or phone bell.

Couples took part in an initial 2.5 hr home visit, during which they were trained in the daily diary protocol and saliva sample collection. The following day, participants started a 7-day daily diary period during which they answered questionnaires (iDialogpad; G. Mutz, Cologne, Germany) and provided concurrent saliva samples 7 times daily (at wake-up, 30 min after wake-up, and at five evenly spaced assessments across the day). The five default times during the day

(10 AM, 1 PM, 4 PM, 7 PM, 9:30 PM) could be adjusted by the research assistants on the day prior to the study to accommodate participant's schedules. On the second day of participation, a research assistant visited the couples to answer any questions and to hand participants a questionnaire package assessing their socio-demographic background, relationship, physical and mental health, and personal goals. At the end of the daily diary period, couples took part in a final session (about 1 hr long), during which they returned study materials as well as the completed questionnaire package to a research assistant and provided feedback on the study. Participants also received a second questionnaire package approximately one year post participation that collected information on additional individual difference measures including empathy, control beliefs, personality, relationship functioning, and well-being. Each participant received 100 € as compensation for their time. The current manuscript makes use of data of 77 couples from a parent sample of 110 dyads, who provided both salivary cortisol and daily diary data. *Table A-2* displays main sample characteristics.

Table A-1: Participant sample characteristics LL project (N = 85 couples)

Variable	**Sample numbers and percentages**	**Variable**	**Sample numbers and percentages**
Age (years)	60-65: *N* = 36 (21.2%) 66-70: *N* = 41 (24.1%) 71-75: *N* = 51 (30.0%) 76-80: *N* = 30 (17.6%) 81-85: *N* = 10 (5.9%) 86-90: *N* = 2 (1.2%)	**Highest education level completed**	Less than 12 years: *N* = 5 (2.9%) High school diploma/GED: *N* = 28 (16.5%) Some college/university: *N* = 25 (14.7%) Trades/professional diploma: *N* = 24 (14.1%) Bachelor's degree: *N* = 51 (25.0%) Master's degree: *N* = 27 (10.9%) Doctoral degree: *N* = 6 (3.3%) Missing: *N* = 4 (2.4%)
Body mass index	16-20: *N* = 11 (7.7%) 21-25: *N* = 66 (46.5%) 26-30: *N* = 48 (33.8%) 31-35: *N* = 14 (9.9%) 36-40: *N* = 1 (0.7%) 41-45: *N* = 2 (1.4%)	**Self-rated health**	1 - Poor: *N* = 2 (1.2%) 2 - Fair: *N* = 39 (22.9%) 3 - Good: *N* = 60 (35.3%) 4 - Very good: *N* = 52 (30.6%) 5 - Excellent: *N* = 17 (10.0%)
Functional comorbidities (out of 27)	*M* = 2.17 chronic conditions, *SD* = 2.00, range: 0 to 9.	**Retirement status**	88.8% retired Both partners retired: n = 70 Both partners employed: n = 4

Table A-2: Participant sample characteristics BCD project (N =77 couples)

Variable	Sample numbers and percentages	Variable	Sample numbers and percentages
Age (years)	60-65: *N* = 0 (0.0%) 66-70: *N* = 18 (11.7%) 71-75: *N* = 80 (51.9%) 76-80: *N* = 48 (31.2%) 81-85: *N* = 8 (5.2%) 86-90: *N* = 0 (0.0%)	**Highest education level completed**	Apprenticeship: *N* = 17 (14.7%) Apprenticeship with vocational school: *N* = 37 (14.1%) Trades/professional degree: *N* = 5 (14.1%) University of applied sciences degree: *N* = 10 (25.0%) University degree: *N* = 61 (10.9%) Doctoral degree: *N* = 6 (3.3%) Missing: *N* = 17 (2.4%)
Body mass index	16-20: *N* = 3 (2.3%) 21-25: *N* = 52 (40.3%) 26-30: *N* = 59 (45.7%) 31-35: *N* = 12 (9.3%) 36-40: *N* = 3 (2.3%) 41-45: *N* = 0 (0.0%)	**Self-rated health**	1 – Very poor: *N* = 0 (0.0%) 2 - Poor: *N* = 8 (5.2%) 3 - Medium: *N* = 57 (37.0%) 4 - Good: *N* = 75 (48.7%) 5 - Very good: *N* = 11 (7.1%) Missing: N = 3 (1.9%)
Functional comorbidities (out of 25)	*M* = 3.22 chronic conditions, *SD* = 2.09, range: 0 to 11.	**Retiremen t status**	92.8% retired Both partners retired: n = 64 Both partners employed: n = 1

Appendix B. L-R coding scheme

The Manifesto Project codes quasi-sentences derived from party's manifestos according to 56 policy categories. The left-right scale is based on 26 of these categories, with 13 categories representing left-wing ideology and 13 categories representing right-wing ideology (Budge, 2013). Left policy categories comprised: anti-imperialism, military (negative), peace, internationalism (positive), democracy, market regulation, economic planning, protectionism (positive), controlled economy, nationalisation, welfare state expansion, education expansion, and labour groups (positive). Right policy categories included: military (positive), freedom and human rights, constitutionalism (positive), political authority, free market economy, economic incentives, protectionism (negative), economic orthodoxy, welfare state limitation, national way of life (positive), traditional morality (positive), law and order (positive), and civic mindedness (positive). Relative emphasis on a topic is calculated by the number of quasi-sentences allocated to the respective topic in proportion to the total number of quasi-sentences. The sum of all left categories is subsequently subtracted from the sum of all 13 right categories. Next, the percentage of party endorsement in each federal state was multiplied with the L-R index of the respective party. Percentages of party endorsement and the final L-R Score for each German federal state can be found in *Table A-3*.

Table A-3 Political party endorsements of the 2017 German federal election and left-right score for each federal state

Federal state	CDU/ CSU	SPD	AfD	FDP	Left	Greens	L-R Score
Baden-Wuerttemberg	0.36	0.17	0.13	0.13	0.07	0.14	-6.16
Bavaria	0.42	0.17	0.13	0.11	0.07	0.11	-4.98
Hamburg	0.29	0.25	0.08	0.11	0.13	0.15	-11.43
Hesse	0.32	0.25	0.12	0.12	0.08	0.10	-7.82
Mecklenburg-Vorpommern	0.35	0.16	0.20	0.07	0.19	0.05	-7.79
Lower Saxony	0.36	0.28	0.09	0.10	0.07	0.09	-8.30
North Rhine-Westphalia	0.34	0.27	0.10	0.14	0.08	0.08	-8.01
Rhineland-Palatinate	0.37	0.25	0.12	0.11	0.07	0.08	-6.90
Saarland	0.34	0.28	0.10	0.08	0.13	0.06	-10.19
Saxony	0.29	0.11	0.29	0.09	0.17	0.05	-4.79
Saxony-Anhalt	0.32	0.16	0.21	0.08	0.19	0.04	-7.63
Schleswig-Holstein	0.35	0.24	0.08	0.13	0.07	0.12	-8.36
Thuringia	0.31	0.14	0.24	0.08	0.18	0.04	-6.40

Appendix C. Synchrony and shared context/activities

Cortisol synchrony in couples may not just be a consequence of interpersonal social processes, but partners reacting to shared experiential context in a similar way may also contribute to cortisol synchrony. One way to address this empirically may be to examine the degree to which partners report shared activities as well as being at the same location when prompted to complete momentary questionnaires over the assessment period. To do so, I created an aggregate score for each couple reflecting how many assessment points partners reported being engaged in the same activity or being at the same location. Couples varied substantially in both indices. For shared activity, the mean score was 37.5% (*SD* = 20.2%, range 0-93%) for the LL project, 40.6% (*SD* = 15.1%, range 9-97%) for the BCD project, and 32.1% (*SD* = 12.7%, range 7-77%) for the ELOC project. For shared location, the mean score was 80.0% (*SD* = 16.9%, range 26-100%) for the LL project, 91.6% (*SD* = 12.9%, range 37-100%) for the BCD project, and 86.0% (*SD* = 13.5%, range 32-100%) for the ELOC project. Most relevant for the question asked, neither score was significantly correlated with cortisol synchrony, see *Table A-4*.

Table A-4: Bivariate correlations between shared experiential context indicators and synchrony

Project	Variable	2	3
LL	1. Cortisol synchrony	.10	–.12
	2. Shared activities		.20
	3. Shared location		
BCD	1. Cortisol synchrony	.08	-.03
	2. Shared activities		.22
	3. Shared location		
ELOC	1. Cortisol synchrony	.04	.03
	2. Shared activities		.12
	3. Shared location		

Note. LL = Linked Lives. BCD = Berlin Couple Dynamics. ELOC = Everyday Life of Older Couples.