# Interpersonal Emotion Dynamics in Couples With Somatic Symptom Disorder: Dyadic Coherence in Facial Temperature During Emotional Interactions

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## ABSTRACT

**Objective:** Disturbances in emotional processes are commonly reported in patients with a somatic symptom disorder (SSD). Although emotions usually occur in social interactions, little is known about interpersonal emotion dynamics of SSD patients during their actual emotional encounters. This study examined physiological coherence (linkage) between SSD patients and their partners, and in healthy couples during their emotional interactions. Secondarily, we explored group-level relationships between participants' and their partners' subjective affect.

**Methods:** Twenty-nine romantic couples (16 healthy and 13 SSD patient-couples) underwent a dyadic conversation task with neutral and anger-eliciting topics followed by a guided relaxation. Partners' cutaneous facial temperature was recorded simultaneously by functional infrared thermal imaging. Immediately after each condition, participants reported on their pain intensity, self-affect, and perceived partner-affect.

**Results:** Emotional conditions and having a partner with an SSD significantly affected coherence amplitude on the forehead ($F(2,54) = 4.95$, $p = .011$) and nose tip temperature ($F(2,54) = 3.75$, $p = .030$). From baseline to anger condition, coherence amplitude significantly increased in the patient-couples, whereas it decreased in the healthy couples. Correlation changes between partners' subjective affect comparably accompanied the changes in physiological coherence in healthy and patient-couples.

**Conclusions:** Inability to reduce emotional interdependence in sympathetic activity and subjective affect during a mutual conflict observed in SSD patient-couples seems to capture emotion co-dysregulation. Interventions should frame patients' emotional experiences as embodied and social. Functional infrared thermal imaging confirms to be an ecological and reliable method for examining autonomic changes in interpersonal contexts.

**Registration Page**: https://osf.io/8eyjr

**Key words:** somatic symptom disorder, couples, interpersonal emotion dynamics, physiological linkage, functional infrared thermal imaging, wavelet coherence analysis.

## INTRODUCTION

Somatic symptom disorder (SSD) is a disturbing condition for the patient and her/his social system, prevalent in the population, and costly for society (1,2). One or multiple bodily symptoms combined with excessive thoughts, feelings, and behaviors concerning the complaints, and significant dysfunction portray the disorder (3). Most common bodily symptoms include pain in different locations, functional disturbances (e.g., dizziness, constipation, diarrhea), fatigue, and exhaustion (4). Cooccurence of depression and anxiety (1), neurocognitive dysfunction in case of comorbid depression (5), personality disorders (6), and other emotional disturbances, such as alexithymia, are also reported in SSD (7,8).

There is abundant evidence for an association between disturbances in emotion processing and regulation and somatic symptoms (9–11). However, little is known about emotional processes during SSD patients' actual interpersonal interactions. Psychosomatic research has generally investigated emotions and social interactions as distinct and separate fields (12,13). This gap is especially problematic under the assumption that emotions have evolved through social interactions (14–16) and are closely connected with interoceptive inference about bodily states associated with SSD (17). Examining how interpersonal emotion dynamics (i.e., interdependent emotional change between individuals) (18) emerge during patients' emotional encounters can help understand the biopsychosocial mechanisms of emotional and bodily disturbances in SSD.

**ANOVA** = analysis of variance, **CI** = confidence interval, **fIRI** = functional infrared thermal imaging, **M** = mean, **MD** = mean difference, **PL** = physiological linkage, **SD** = standard deviation, **SSD** = somatic symptom disorder, **WCA** = wavelet coherence analysis

SDC Supplemental Digital Content

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Received for publication December 17, 2020; revision received June 17, 2021.

DOI: 10.1097/PSY.0000000000001032

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The present study aimed to investigate one aspect of interpersonal emotion dynamics in couples with an SSD patient and healthy couples during their emotional interactions: physiological linkage[1] (PL), defined as the covariance of two or more people's physiology in time (22). PL between individuals has attracted increasing attention owing to its psychosocial and health-related implications (20,21,23–27). Especially the last decade has witnessed an exponential interest along with technological developments that enabled complex measurement and analytical methods (21). However, to date, PL has been investigated mostly in healthy populations, and it remains unclear how it is manifested during SSD patients' emotional interactions.

Emotions do not occur in a vacuum; *persons* live through them, mostly during social encounters. When people engage in emotional interaction, they share and coordinate their feelings, movements, behaviors, and even physiological responses. Social and dynamical systems framework underlines this coordination as a continuously changing process that ensues interdependently between interactants (15,28,29). One of the channels where emotional interdependence occurs is physiology, whereby physiological response systems of two or more persons covary (22).

Research has shown competing evidence regarding the health-related implications of PL. On the one hand, it has several positive associations, such as empathy and understanding (30–32), relationship satisfaction (33), emotion coregulation (34), sharing of emotional burden (35), adaptive mother-child functioning (24), and lower risk for psychopathology (26). On the other hand, PL during conflict seems to have adverse psychological and physical implications, such as relationship dissatisfaction (25) and distress (22), negative affect reactivity, and high inflammatory markers (27).

Overall, the studies suggest that the context in which an emotional interaction occurs matters in the implications of PL. It might facilitate attunement and understanding in a positive context, and sharing of burden in situations against external stimuli. However, when reacting to each other, such as a mutual conflict, PL may have disruptive effects, such as negative affect reciprocity, escalation, and emotion co-dysregulation (20,28). A recent study supports this proposition, which found that interacting persons felt good when they were high in movement synchrony but felt less capable of self-regulation (36).

During a conflict, PL was associated with endocrinological distress signatures. In a study with healthy couples, increased linkage in heart rate variability during conflict predicted heightened inflammatory markers across the day of interaction (27). Another study showed significant associations between partners' daily cortisol levels, which was more significant when the couples were together, a relationship that diminished as the marital satisfaction improved (37). Partner's linkage in cortisol levels was also shown to be present in a longer time scale. A longitudinal study has observed significant linkage in newly married healthy spouses' cortisol trajectories during the conflict, a pattern that became more robust as their relationship matured (25).

[1]In the literature, the overarching term "physiological linkage" is generally used. However, depending on the analysis method, several terms exist in different fields referring to PL, such as synchrony, coupling, and coregulation. See the reviews (19–21) for an overview. Throughout this article, we use the overarching term "linkage" when reviewing the literature but specify it as "physiological coherence" in our work, which reflects the analysis method we used (wavelet coherence analysis).

Although the studies suggest a relationship between PL and health outcomes in healthy couples, to our knowledge, no study examined PL in patients with SSD and their partners. The present work aimed to compare whether and how PL in SSD patient-couples is different from that in healthy couples in neutral, anger-eliciting, and relaxing contexts in a laboratory setting. We also explored the relationship between both partners' subjective affect and their perceived partner-affect after these emotional interactions to complement the physiological findings.

We examined PL by measuring cutaneous temperature on the facial regions of interest via functional infrared thermal imaging (fIRI). fIRI is a widespread and contactless method to examine autonomic physiology (38–42). It records the dynamic distribution of skin temperature by imaging the infrared radiation emitted from the skin at a distance. Cutaneous temperature is regulated by the autonomic nervous system to maintain homeostasis against changing external conditions. It reflects sympathetic and parasympathetic regulation mainly through cutaneous perfusion and sweat gland activation (38,41,42). Especially through vasoconstriction and vasodilation, the autonomic nervous system can regulate the skin blood flow that helps an organism to get into a fight or flight response or socially engage (41,43). For example, skin blood flow and thermal prints coincided in 92% of vasoconstrictions during stressful occasions in a study (43).

fIRI has a high temperature and time-spatial resolution and does not require the attachment of electrodes or cables, enabling experiments in ecological settings (42). Therefore, interpersonal paradigms have used this measure (30,31,40). Also, in human-robot interactions, researchers develop algorithms to develop autonomous systems to classify emotions with the help of fIRI, reaching up to 60% to 90% accurate classification (44).

There is compelling evidence for disturbances in emotional processing and regulation in SSD (9–11). Accordingly, during a conflict, we expect a higher physiological coherence in SSD patient-couples than baseline, which is associated with stress reactivity or escalation in a mutual conflict (20,27,28), and diminished self-regulation (36). On the other hand, based on previous evidence for the functionality of PL in facilitating empathy and attunement in positive or neutral contexts, we expect healthy couples to show higher PL at baseline but to attenuate it during anger, as an adaptive means to disengage from the conflict.

As a secondary aim, the present study examines how the relationship between partners' affect changes among experimental conditions. We investigate the group-level relationships between the partners' a) actual affect (emotional similarity), b) self-affect and perceived partner-affect (assumed similarity), and c) perceived partner-affect and the partners' actual affect (empathic sensitivity) (45). Based on the aforementioned studies, which suggested PL to reflect psychological interdependence, we expect that SSD patient-couples will show a greater between-dyad emotional interdependence (i.e., relationship) at anger than baseline condition, whereas healthy couples show the opposite pattern of a weaker emotional interdependence during anger compared with the baseline condition.

## METHODS

### Participants

An a priori analysis with G*Power (46) suggested a sample size of 28 with an expected power of 80% and medium effect size for a within-between



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interaction effect in a mixed-effects analysis of variance (ANOVA; two groups, three measures, $\alpha = .05$). We consecutively recruited 31 committed couples to the study. One patient-couple dropped the study during baseline, and one partner of a healthy couple reported long-term migraine and back pain during our pain screening. After excluding these two couples, the final sample consisted of 29 couples ($n = 58$) in two groups: healthy couples ($n_{couples} = 16$, aged between 21 and 61 years; mean [standard deviation] age, or $M_{age}$ [SD] = 38.2 [13.1]) and couples with a partner with an SSD (SSD patient-couples; $n_{couples} = 13$, aged between 30 and 61 years, $M_{age}$ [SD] = 45.9 [7.8] years). With two exceptions, patients were female. Approximately one-third of the couples' relationship length ranged from 1 to 4 years, and another third ranged from 4 to 15 years. There was no significant difference in relationship length between couples (Table 1).

We recruited patient-couples through the inpatient and outpatient units of the Department of Psychosomatic Medicine and Psychotherapy at the Technical University of Munich. To keep homogeneity in the sample, we focused on SSD with predominant pain. The inclusion and exclusion criteria and the clinical diagnoses for all the patients were established by experienced and trained clinicians of the department, by conducting an extensive interview to evaluate the clinical characteristics for the diagnoses in question, including a detailed somatoform disorders and hypochondria symptom assessment. Healthy couples were recruited through advertisements in the departments' internal magazines, intranet and flyers, or local newspapers.

The inclusion criteria were as follows:

a) a diagnosis with somatoform pain (*International Classification of Diseases, Tenth Revision* F45.40) or chronic pain with psychological factors (F45.41) for the patients. (A *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*/SSD diagnosis was confirmed post hoc by checking the complete B-criterion)
b) being free of any chronic somatic complaints, for the healthy controls
c) a current romantic relationship for at least 1 month and the partner's consent for participation for all the participants

Exclusion criteria for all participants were a) age younger than 18 years, b) inadequate command of German, c) severe and chronic physical disease, d) severe comorbid mental disorder causing significant impairment of social functioning, and e) severe conflict in the relationship.

The data were collected in March 2014. The Ethics Commission of the Department of Medicine of the Technical University of Munich approved the study. All participants were informed about the study and signed an informed consent form before starting the experiment. Couples received 100 euro for participation.

## Procedure

Participants were asked not to take any stimulants (e.g., coffee, tea, nicotine) less than 2 hours before testing and not to wear any makeup. Upon arrival at the laboratory, they filled in questionnaires on demographic information, somatic complaints (Patient Health Questionnaire-15), and psychosocial stressors (Patient Health Questionnaire-10) (47). Next, the couples underwent a dyadic interaction paradigm that consisted of three conditions (Figure 1). An intern-psychotherapist blind to the study hypotheses moderated the interactions. During the three conditions, the cutaneous temperature of both partners was measured. After each condition, participants reported their current affect and perceived partner-affect by a self-report instrument explained hereinafter.

### *Dyadic Emotion Induction Tasks*

#### *Baseline Interaction*

Couples had an approximately 5-minute conversation about an emotionally neutral event such as the trip to the laboratory, events of the day, or the weather, as suggested by previous studies (22).

#### *Anger-Eliciting Interaction*

Based on previous research having underlined anger-regulation difficulties in patients experiencing chronic pain (11,48), we focused on an anger context. Interview methods are more effective in creating physiological

**TABLE 1.** Sample Characteristics

| Variable | M (SD) or *n* (%) | | | | ANOVA/$\chi^2$ Test $F/\chi^2$ Value | Post Hoc Group Comparison |
|---|---|---|---|---|---|---|
| | 1 Patients ($n = 13$) | 2 Partners of Patients ($n = 13$) | 3 Healthy Controls ($n = 16$) | 4 Partners of Healthy Controls ($n = 16$) | | |
| Age, M (SD), y | 42.58 (6.98) | 49.64 (7.12) | 37.07 (13.38) | 39.27 (13.32) | 2.98* | 2 > 3 ($p_{bonf} = .04$) |
| Sex, no. female (%) | 11 (85) | 2 (15) | 14 (87) | 2 (13) | 30.46*** | 1 > 2, 3 > 4 ($p_{bonf} < .05$) |
| Education, M (SD), y | 14.20 (4.56) | 15.85 (3.95) | 16.88 (2.50) | 16.38 (2.96) | 1.33 | — |
| Cohabitation, no. yes (%) | 9 (75) | | 12 (75) | | 1.00 | — |
| Relationship length, *n* (%) | | | | | | |
| 1–12 mo | 0 | | 1 (6.3%) | | 0.97 | — |
| 1–4 y | 6 (46) | | 6 (37.5) | | | |
| 4–15 y | 5 (38.5) | | 5 (31) | | | |
| 15 yr | 2 (15) | | 4 (25) | | | |
| Somatic Pain (PHQ-15), M (SD) | 12.80 (6.81) | 3.18 (3.65) | 3.88 (3.51) | 3.00 (2.90) | 15.83*** | 1 > 2, 3, 4 ($p_{bonf} < .001$) |
| Relationship distress (PHQ-10d), M (SD) | 0.92 (0.79) | 0.62 (0.77) | 0.40 (0.63) | 0.36 (0.50) | 1.84 | — |
| Stress (PHQ-10), M (SD) | 9.92 (4.38) | 4.85 (4.56) | 4.00 (2. 80) | 2.93 (2.1) | 8.78*** | 1 > 2, 3, 4 ($p_{bonf} = .008, .001, .000$) |

M (SD) = mean (standard deviation); ANOVA = analysis of variance; PHQ = Patient Health Questionnaire (47).

* $p < .05$.

** $p < .01$.

*** $p < .001$.



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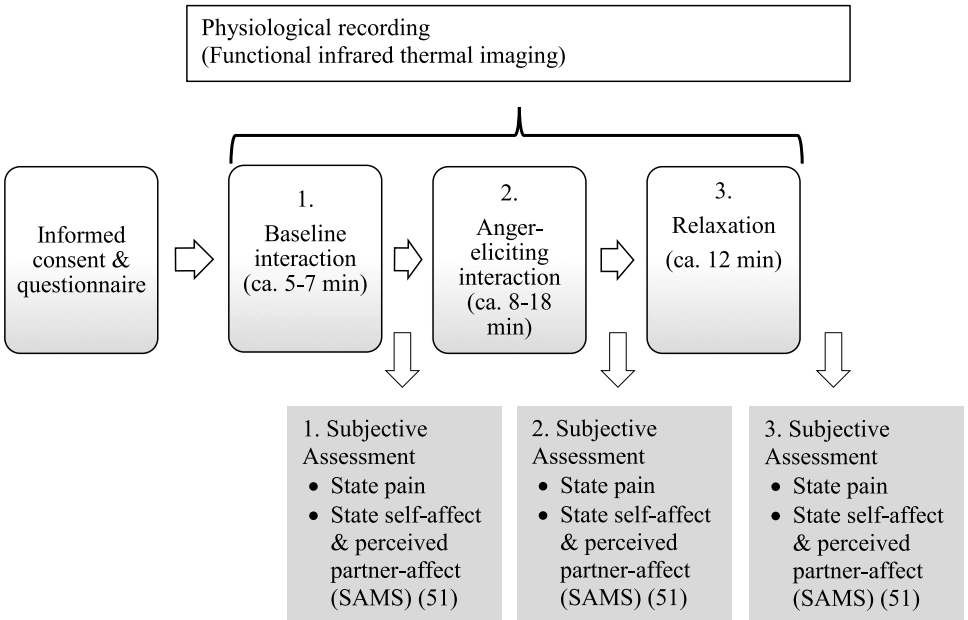



**FIGURE 1.** Experimental procedure. SAM = Self-Assessment Manikin.

variations than other methods, such as movie clips or punishment tasks (49). Therefore, we chose the dyadic interview method for anger induction. For this task, the interviewer instructed the partners to identify a mutual past event that generated a strong feeling of anger toward each other on both sides, an experience that could still be well recalled by the two. One of the partners was instructed to describe the event verbally. The interviewer then instructed them to discuss the event, their thoughts, and feelings as genuinely as possible (50). The interviews lasted between 8 and 18 minutes (M [SD] = 15.73 [2.29] minutes).

#### *Relaxation*

To downregulate the negative affect, the couples followed a guided audio progressive-muscle relaxation and imagination exercise that lasted about 12 minutes.

## Measures

### *Thermal Variations on the Face*

Infrared imaging was run using two digital cameras: FLIR, SC660 (640 × 480 bolometer, focal plane array, sensitivity: <30 mK at 30°C), and FLIR SC655 (640 × 480 bolometer, focal plane array, sensitivity: <50 mK at 30°C). The sampling rate was five frames per second. The cameras were positioned behind and just over each partner's head so that each camera could record the partner's face. The experiment room had an average temperature between 20°C and 23°C (60% to 65% humidity) and was isolated from direct ventilation and sunlight. Variations in the cutaneous temperature of the facial regions of interest were analyzed using customized MATLAB programs developed for tracking purposes and validated in previous studies (30,51). Our primary regions of interest, a) the nose and b) the forehead, were selected based on previous studies (30,41,42). The thermal signals were obtained as pixels' average values on the regions of interest over time. After the thermal imprints were inspected visually for the recording quality, the thermograms were corrected for movement artifacts.

### *Subjective Reports for Pain and Affect*

Immediately after each condition, participants rated their pain with a visual analog scale. They also rated their affect and perceived partner-affect on a paper-based scale. This method enabled us to quantify subjective emotional interdependence at a between-couple level. The scale involved items that assess the pleasure, arousal, and dominance dimensions for both self and partner (e.g., "How do you feel right now?" "How does your partner feel right now?"; adapted from Self-Assessment Manikin (52); see the Data, Supplemental Digital Content 1, http://links.lww.com/PSYMED/A799, for example items). Self-Assessment Manikin is a cartoon-like visual assessment of affect, hence a quick and implicit scale. It has a 9-point scoring system for measuring feelings of valence (unhappy to happy), arousal (calm to excited), and dominance (controlled to controlling), with a pictorial representation for each point.

## Data Analysis Strategy

First, we performed mixed-model ANOVAs for unbalanced designs to examine the within-subject effect of experimental condition (baseline, anger, relaxation) and between-subject effect of individual groups (patients, their partners, healthy controls, and their partners) on each affect dimension (i.e., valence, arousal, and dominance). Post hoc tests were adjusted for Bonferroni corrections. To test the effect of experimental conditions on pain experience, we compared pain reporters' self-ratings by paired-samples *t* tests.

To examine coherence between partners' cutaneous facial temperature, we performed wavelet coherence analysis (WCA) for each couple. WCA is a frequency and time-domain analysis that evaluates similar patterns of variations between two signals. It decomposes time-series data into components with different frequencies or rhythms at a time-frequency space (53,54).

Autonomic data are usually nonstationary; that is, the statistical properties of the data, such as mean and variance, change over time. WCA does not assume the data's stationarity and can detect the cyclical changes at different frequency bands (54). Many physiological signals contain frequency bands related to biological and clinical indications, such as respiratory sinus arrhythmia of an electrocardiac signal or the frequency bands of cutaneous blood flow. WCA can detect different frequency components and inform about a thermal signal's physiological origins (55). Besides, it requires little parameter estimates (54). Other methods to quantify linkage, such as windowed cross-correlation, are sensitive to parameter estimates and require informed decisions, making it prone to subjectivity.

WCA on thermal signals was performed via the MATLAB package provided by Grinsted et al. (53) (http://noc.ac.uk/using-science/



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crosswavelet-wavelet-coherence) using the Morlet wavelet as the mother wavelet. Based on previous studies, we distinguished five frequency bands for cutaneous temperature: metabolic (0.008–0.02 Hz), neurogenic (0.02–0.05 Hz), myogenic (0.05–0.15 Hz), respiratory (0.15–0.4 Hz), and cardiac origins (0.4–2 Hz) (56,57). (56,57). For each experimental condition of each couple and frequency band, the average coherence amplitude over time was computed. Furthermore, the percentages of in-phase and antiphase values were calculated, replicating the approach used in previous studies (54,58). Although low-frequency bands (i.e., metabolic, myogenic, and neurogenic) carry information about modulation of microvascular flow motion at a local level, high-frequency bands (i.e., cardiac and respiratory) reflect hemodynamic modulation by breathing and heartbeat (59), making them prone to short-time emotional changes. Therefore, we tested our hypothesis on the cardiac band, which exhibits the highest frequency. Because it is not established which frequency band to focus on during emotional contexts, we also exploratively ran the analysis for each frequency band.

Coherence amplitude values indicate the strength of the linkage between signals, regardless of the direction, which is the main interest of our study. Coherence amplitude values range between 0 and 1, with 0 representing no linkage and 1 indicating a total linkage in temperature. In-phase and antiphase values provide information on the relative phase angle of two signals: the covariation of timing. If two signals are in-phase, they move in the same part of a cycle simultaneously, comparable to a positive correlation. If the signals are in antiphase patterning, they move in the opposite part of a cycle (see Figure 2 for an illustration of a couple's temperature time series mapped on a WCA plot).

We then performed two 2 × 3 mixed-model ANOVAs to test the interaction effect of the couple type and experimental conditions on the coherence amplitude at the cardiac band in the nose tip and forehead temperature.

Finally, to explore the between-couple level interdependence in partners' subjective affect, we performed nonparametric correlation analyses. We did not include the relaxation condition beyond this study's primary focus to reduce the number of analyses.

## RESULTS

### Preliminary Analyses: Effect of Experimental Conditions on Individual Responses

#### *Change of Affect*

Experimental conditions significantly changed participants' positivity (valence; $F(2,108) = 43.48$, $p < .001$, $\eta^2 = 0.29$), arousal ($F(2,108) = 84.84$, $p < .001$, $\eta^2 = 0.36$), and dominance ($F(2,106) = 3.22$, $p = .044$, $\eta^2 = 0.03$; Figure 3). As expected, positive affect significantly decreased from baseline to anger (mean difference [MD] = −1.84, SE = 0.26, $t = -7.16$, $d = -0.94$, $p_{bonf} < .001$) and increased at relaxation (MD = −2.17, SE = 0.26, $t = -8.34$, $d = -1.09$, $p_{bonf} < .001$). When couples were compared, SSD patient-couples reported a slight lower positive affect than healthy couples ($F(1,56) = 3.82$, $p = .056$, $\eta^2 = 0.64$). Arousal followed an opposite pattern to valence: a significant increase from baseline to anger (MD = 1.27, SE = 2.25, $t = 5.19$, $d = 0.68$, $p_{bonf} < .001$) and relaxation (MD = 1.69, SE = 2.23, $t = 7.49$, $d = 0.98$, $p_{bonf} < .001$) and a decrease from anger to relaxation (MD = 2.97, SE = 0.23, $t = 12.93$, $d = 1.70$, $p_{bonf} < .001$). Feeling of dominance declined significantly from anger to relaxation (MD = 0.70, SE = 0.27, $t = 2.55$, $d = 0.34$, $p_{bonf} = .044$). The four groups (patients, their partners, healthy controls, and partners) did not show statistically significant differences from each other in their affect ratings.

#### *Change of Pain*

Because not all the participants reported pain in the experiment, to maintain normal distribution, we selected those who reported pain in all three conditions[2] ($n = 12$) and performed paired-samples $t$ tests. Pain reports increased significantly from baseline (M [SD] = 4.16 [2.33]) to anger (M [SD] = 5.33 [2.06]; $t(11) = -3.19$, $p = .009$, $d = 0.92$, 95% confidence interval [CI] = −1.59 to −0.22), and slightly decreased from anger to relaxation (M [SD] = 4.17 [2.69]; $t(11) = 1.76$, $d = 0.51$, $p = .10$, 95% CI = −0.104 to 1.103).

### Do Couple Group and Emotional Conditions Affect Coherence in Partners' Facial Temperature?

#### *Coherence in Partners' Forehead Temperature at the Cardiac Band*

Coherence amplitude ranged between 0.24 (SD = 0.019) and 0.32 (SD = 0.014). As expected, coherence amplitude between partners' forehead temperature significantly changed as a function of couple type and experimental condition ($F(2,54) = 4.95$, $p = .011$), with a medium effect size ($\eta^2 = 0.1$; Figure 4). Planned follow-up paired-samples $t$ tests showed that coherence significantly decreased in the healthy couples from baseline to anger ($t(15) = 2.13$, $p = .025$, $d = 0.53$) and increased in the SSD patient-couples ($t(12) = -1.91$, $p = .040$, $d = 0.53$).

#### *Coherence in Partners' Nose Tip Temperature at the Cardiac Band*

The amplitude of coherence values between partners' nose tip temperature ranged between 0.22 (SD = 0.017) to 0.31 (SD = 0.016). As expected, a significant interaction effect of couple type and experimental conditions on the coherence amplitude was found ($F(2,54) = 3.75$, $p = .030$), with a small to medium effect size ($\eta^2 = 0.04$; Figure 4). Planned follow-up paired-samples $t$ tests showed that the coherence amplitude of healthy couples' nose tip temperature significantly decreased from baseline (M [SD] = 0.30 [0.02] to anger (M [SD] = 0.28 [0.02]; $t(15) = 4.59$, $p < .001$, $d = 1.15$). No statistically significant change was observed in the patient-couples from baseline to anger condition ($p = .34$, $d = -0.11$).

### Secondary Analyses

#### *Subjective Emotional Interdependence at Between-Couple Level*

*Valence*

*Relationship Between Partners' Valence (i.e., Actual Similarity).* At baseline, although self-valence ratings showed a significant positive relationship in healthy couples ($r_s = 0.595$, $p = .015$, $n = 16$, 95% CI = 0.141 to 0.842), they showed a nonsignificant negative relationship in SSD patient-couples ($r_s = -0.173$, $p = .57$, $n = 13$; Fisher $z = -2.045$, $p = .020$). In the anger condition, this relationship decreased in the healthy couples ($r_s = 0.030$, $p = .91$; Fisher $z = 1.67$, $p = .047$), whereas we observed a nonsignificant yet descriptively increasing positive relationship in the SSD patient-couples ($r_s = 0.364$, $p = .22$, $n = 13$; Fisher $z = 1.24$, $p = .107$; Figure 5).

[2]When the whole sample is included, pain reports again increased significantly from baseline (M [SD] = 0.98 [1.99]) to anger (M [SD] = 1.26.33 [2.36]), $t(56) = -2.08$, $p = .042$, $d = 0.27$, 95% CI = −0.54 to −.01).



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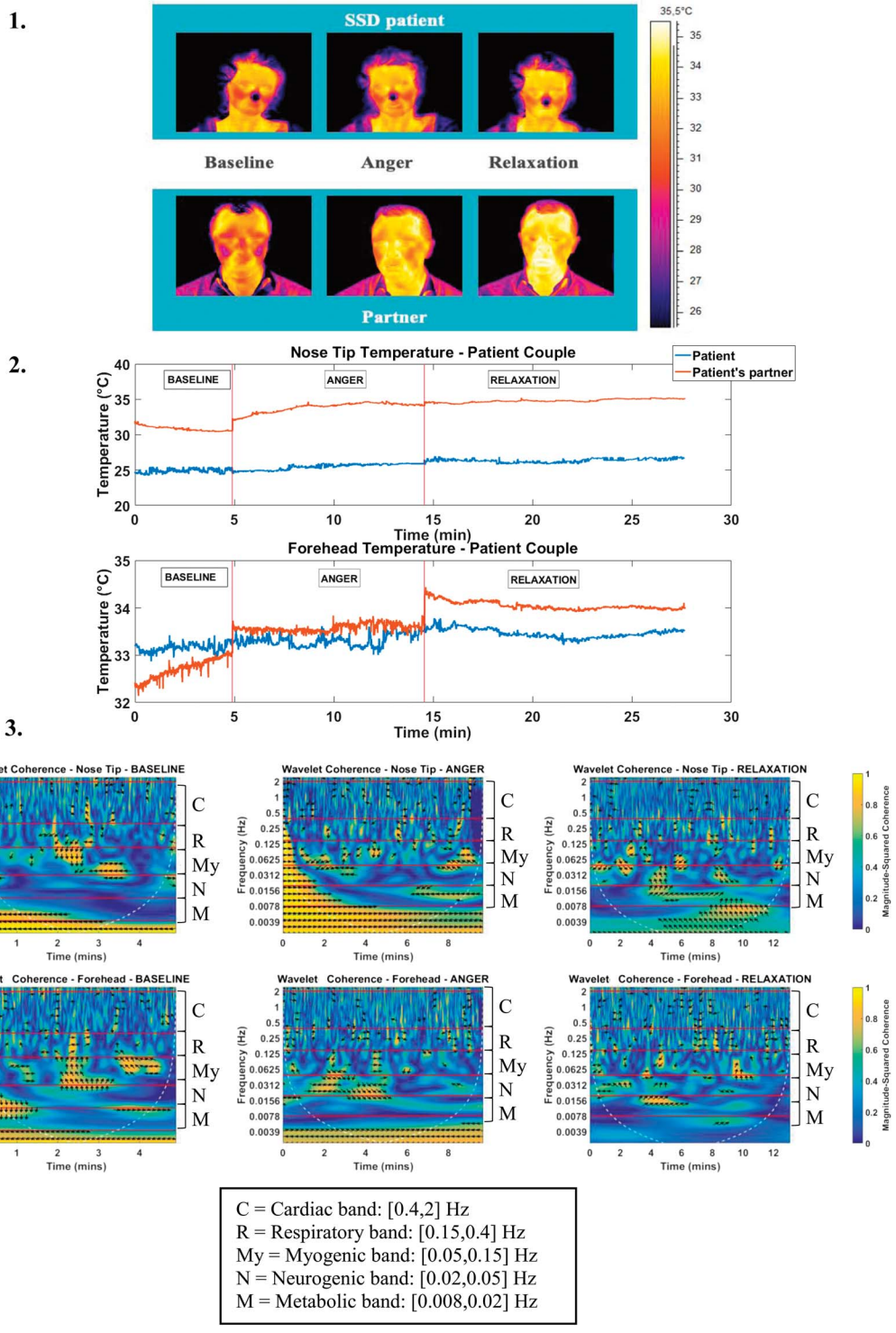



**FIGURE 2.** An illustration of a couple's fIRI image frame (1), and temperature change on the forehead and nose tip on a time-series plot (2) and on a wavelet coherence plot (3). In 3, the *x* axis represents the time, and the *y* axis represents the frequency band. The wavelet coherence amplitude is represented by color. The relative phase is signified by the arrows' direction: The horizontal right arrows indicate complete in-phase patterning, whereas the horizontal left arrows indicate complete antiphase patterning, and the downward arrow indicates no coherence. The average value was calculated from these plots for analyzing the wavelet coherence amplitude and the relative phase. fIRI = functional infrared thermal imaging.



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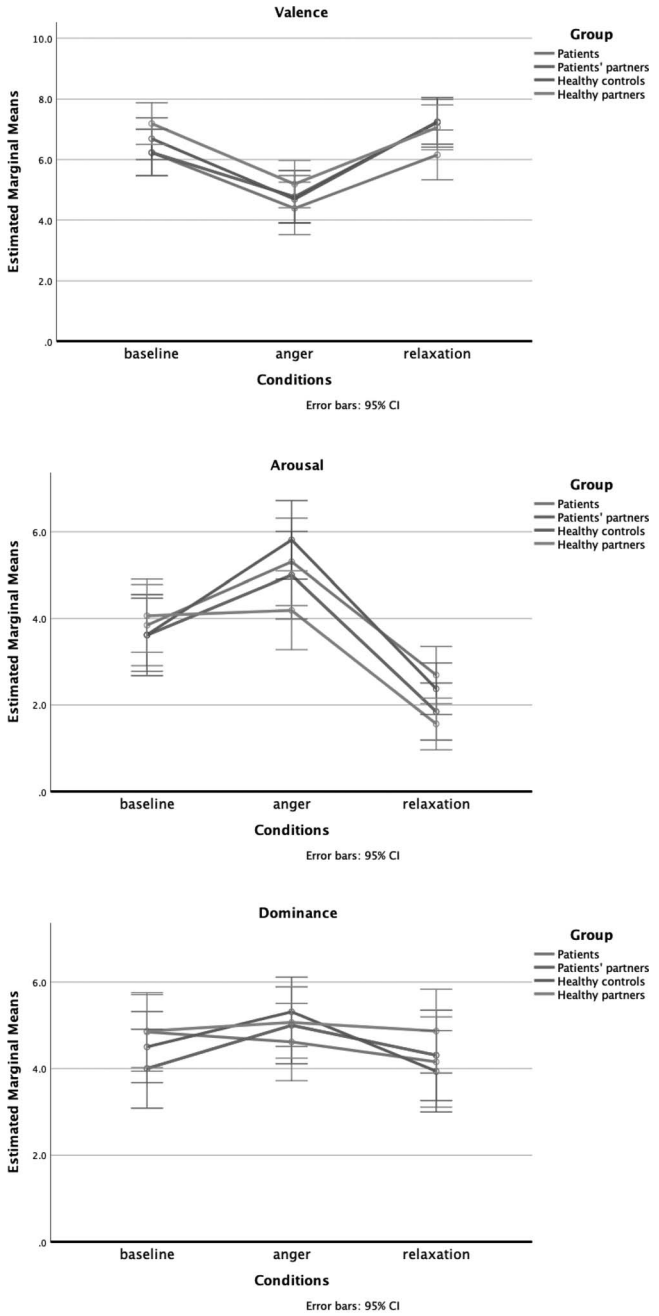



**FIGURE 3.** Change of affect dimensions among experimental conditions. CI = confidence interval.

*Relationship Between Subjects' Self-Valence and Perceived Partner's Valence (i.e., Assumed Similarity).* At baseline, in both couple groups, participants' valence and perceived partner-valence were strongly positively correlated (patient-couples: $r_s = 0.917$, $n = 26$, $p < .001$, 95% CI = 0.821 to 0.962; healthy couples: $r_s = 0.786$, $n = 32$, $p < .001$, 95% CI = 0.602 to 0.891). This relationship remained strong in the patient-couples from baseline to anger ($r_s = 0.663$, $n = 26$, $p < .001$, 95% CI = 0.371 to 0.836). However, it significantly decreased to a medium-sized correlation in the healthy couples ($r_s = 0.400$, $n = 32$, $p = .023$, 95% CI = 0.06 to 0.66; Fisher $z = 2.34$, $p = .008$).

*Relationship Between Perceived Partner-Valence and Partners' Actual Valence (i.e., Empathic Sensitivity).* At baseline, in the patient-couples, perceived partner-valence and partners' true valence were not related to each other ($r_s = -0.107$, $n = 26$), as opposed to the healthy couples who presented a strong relationship ($r_s = 0.661$, $n = 32$, $p < .001$, 95% CI = 0.406 to 0.891; correlation difference between healthy and patient-couples: Fisher $z = 3.19$, $p = .001$). On the other hand, the pattern reversed in the opposite direction at the anger phase: perceived partner-valence and partners' actual valence were related only in the patient-couples ($r_s = 0.413$, $n = 26$, $p = .036$, 95% CI = 0.031 to 0.690; correlation



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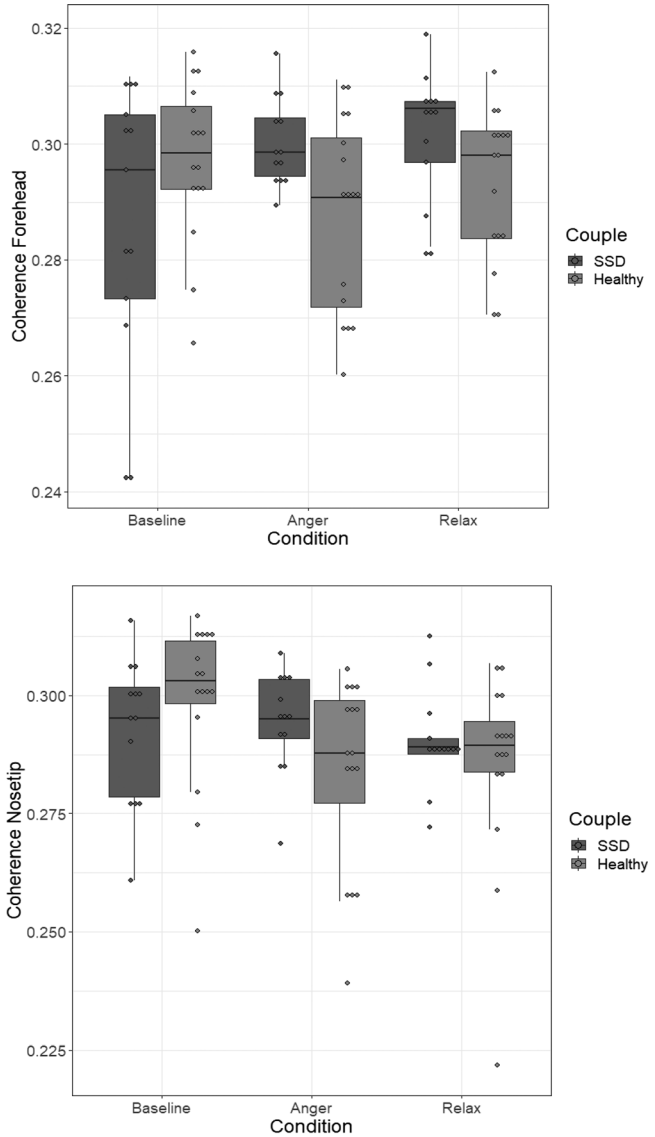



**FIGURE 4.** Change of coherence amplitude in forehead and nose tip temperature among experimental conditions in healthy and SSD patient-couples. SSD = somatic symptom disorder.

difference between baseline and anger condition in the patient-couples: Fisher $z = 1.85$, $p = .032$). However, there was no relationship between estimated and actual feelings of partners in healthy couples ($r_s = 0.193$, $n = 32$; correlation difference between baseline and anger condition in the healthy couples: Fisher $z = 2.28$, $p = .011$).

### *Arousal and Dominance*

Correlation analyses for dominance and arousal dimensions mostly produced nonsignificant results; therefore, the results are reported in Graphs, Supplemental Digital Content 2, http://links.lww.com/PSYMED/A800. However, different patterns of change from baseline to anger condition were observed in SSD patient and healthy couples. The results suggested an increasing between-couple interdependence in arousal and a decreasing one in dominance from baseline to anger condition in the patient-couples.

## *Relative Phase Patterning in Cutaneous Temperature Coherence*

For the change of relative phase patterning (in-phase and antiphase) among conditions, the results were inconclusive (see the Graphs, Supplemental Digital Content 3, http://links.lww.com/PSYMED/A801, which demonstrate the difference in relative phase).

## *Coherence at the Metabolic, Neurogenic, Myogenic, and Respiratory Bands of the Cutaneous Temperature*

In the lower-frequency bands, coherence amplitude ranged between 0.048 and 0.701. Temperature coherence in these frequency bands in the forehead region changed as a function of experimental condition only. In both groups, coherence values in the lower-frequency bands (i.e., metabolic, neurogenic, and myogenic) decreased from baseline to anger and slightly increased during relaxation (metabolic: $F(2,54) = 3.28$, $p = .045$, $\eta^2 = 0.09$; neurogenic:



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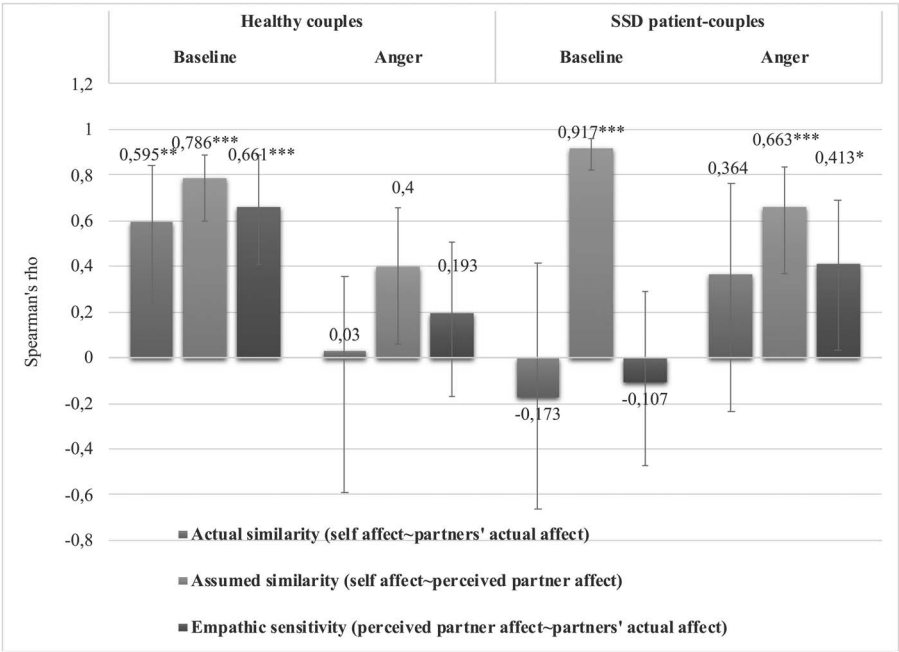



**FIGURE 5.** Relationship between participants' valence reports for self and partner in healthy and SSD patient-couples among baseline and anger conditions. Error bars represent 95% confidence intervals for *r* values. * $p < .05$, ** $p < .01$, *** $p < .001$. SSD = somatic symptom disorder.

$F(2,54) = 3.41$, $p = .040$, $\eta^2 = 0.08$; myogenic: $F(2,54) = 2.05$, $p = .14$, $\eta^2 = 0.05$; Graphs, Supplemental Digital Content 4, http://links.lww.com/PSYMED/A802). For the nose tip temperature, the results were inconclusive.

## DISCUSSION

This study demonstrated that couples with an SSD patient and healthy couples showed different trajectories in emotional interdependence depending on the emotional context. From baseline to anger-eliciting interaction, healthy couples could decrease their physiological coherence, whereas SSD patient-couples showed a stronger coherence amplitude. Between-couple level subjective emotional interdependence between partners followed a similar course to physiological coherence in both couple groups. Notably, in the SSD patient-couples, interdependence of emotional valence seemed completely absent at baseline, whereas healthy couples showed evidence for a strong relationship during this condition. This relationship between partners took an opposite direction in the anger condition: SSD couples showing a stronger and healthy couples showing a weaker emotional interdependence.

Our findings are in line with previous reviews, which concluded that the implications of PL depend on the context (20,21,28). Healthy couples' higher temperature coherence at baseline might point to their emotional connectedness and understanding, as indicated by previous studies (30–32). This interpretation is supported by their greater between-couple level subjective emotional interdependence at baseline, conveying higher assumed similarity, actual similarity, and empathic sensitivity between partners. However, at the anger condition, the decrease in emotional interdependence in the healthy couples can denote a functional and adaptive shift to a more independent emotional processing to prevent escalation and dyadic emotional overload (20).

On the other hand, SSD patient-couples' stronger temperature coherence and emotional interdependence at the anger condition can convey inability to disengage from a negative emotional exchange, featured by patterns of reactivity and counterreactivity (20,27,28). Patient-couples' slightly lower valence ratings in general and the increasing positive relationship between partners' arousal from baseline to anger, in contrast to the negative one in the healthy couples, lend support to our conclusions.

### Limitations and Future Directions

Some characteristics of this study limit the conclusions we can draw about the effect of having an SSD patient partner and emotional context on physiological coherence. First and foremost, the sample size was small, and healthy and patient-couples were not matched based on age and sex, limiting the results' generalizability. Future studies with a larger sample size are called for to replicate or extend the study findings. Second, we observed considerable variability in physiological coherence across couples that future studies can examine by including possible couple characteristics such as attachment styles or emotion regulation variables. This heterogeneity might be an essential feature associated with individual differences in the relationship between psychological and physical health (60). Third, the measured physiological system (e.g., hypothalamic-pituitary-adrenal axis, autonomic nervous system, sympathetic or parasympathetic branch) can play a role in coherence. Future research can compare coherence in other physiological indices. Fourth, the current goal of the study was not to elicit a specific anger response but rather to compare the changes in physiology and emotional experience during presentation of autobiographical anger-eliciting and relaxing content. Therefore, the results do not intend to distinguish whether, or under which conditions, the physiological reaction is explicitly linked to anger and



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not to a nonspecific emotional arousal or an actual experience of pain during the experiment. Finally, we measured subjective affect by one time-point measure after each condition and then conducted nomothetic analyses (i.e., correlation) to examine between-couple level interdependence. Therefore, it is an open question, whether continuous measurement of subjective affect such as a rating dial method (22) and dyad-level analyses would yield comparable results.

Despite its limitations, this research offers novelty and insight in several ways. The present study integrates the most recent theoretical and methodological developments in emotion research into research on SSD. It enhances our understanding of emotions from an individual state to a multicomponential, dynamic, and interpersonal process to discern the mechanisms of SSD. The interpersonal and ecological design of the research provides critical insight into dynamic and real-time processes taking place during patients' interactions with significant others. Moreover, the study illustrates the potential usefulness of advanced interdisciplinary tools such as WCA or fIRI in psychosomatic research for examining emotional processes.

The present findings provide insights to the healthcare communities for assessing and treating disturbances in emotion regulation (9,11) in patients with SSD. Patients are embedded in their social networks, and it is usually a social encounter where strong emotions such as anger arise and linger. The findings suggest that conflictual situations, such as anger-eliciting ones, can increase SSD patients' autonomic and emotional interdependence with their partners, which seems to be disruptive for physical health (27). These effects are valuable for clinical interventions: During psychotherapy, patients' awareness can be improved on how negative emotions arise and resonate on the body in both interacting parties during emotional exchanges and how they are connected with bodily symptoms. With the patient, self-regulation techniques for dealing with strong emotions during such situations, without getting absorbed by the interdependent dyadic conflictual system, can be developed. Based on the rationale that the quality of interpersonal relationships is likely to constitute and/or influence physical complaints (61), those approaches will be suited to enrich and extend the spectrum of useful therapeutic interventions.

To sum up, the present study showed that having an SSD patient-partner and emotional condition affected within-couple level autonomic and between-couple level subjective emotional interdependence. Emotional interdependence can be seen as a "double-edged sword" (20), which might indicate connectedness and empathy in positive situations or as a response to the external world's demands. Nevertheless, it can denote emotion co-dysregulation during partners' negative emotions directed at each other and might embody being trapped in an adverse affect-mutuality (28), losing autonomy and self-regulation (36). Investigating such dynamic emotional processes in SSD patients' real-time social interactions is essential to understand the psychobiological mechanisms of SSD.

*Source of Funding and Conflicts of Interest: This work was supported by the Marie-Curie Initial Training Network, "TESIS: Towards an Embodied Science of Intersubjectivity" (FP7 PEOPLE-2010-ITN, 264828), Avicenna-Studienwerk funded by the German Federal Ministry of Education and Research (BMBF), and grant C14/19/054 from the KU Leuven Research Council. The authors declare that no conflict of interest exists.*

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