Social Science & Medicine 284 (2021) 114220

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Physiological linkage during interactions between doctors and cancer patients

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ARTICLE INFO

Keywords:
Doctor-patient interaction
Doctor-patient relationships
Physiological linkage
Relationship length
Continuity of care
Oncology
Cancer
Non-linear dynamics

ABSTRACT

Introduction: Doctors and patients influence each other when interacting and, as a result, can become similar to each other in affect and behavior. In the current work, we examine whether they also become similar to each other on a moment-to-moment basis in their physiological responses. Specifically, we examine *physiological linkage*—how much a doctor's (or patient's) physiological response predicts a patient's (or doctor's) response at a subsequent time interval—and whether this changes over the course of doctor-patient relationships (measured as the number of consultations held for each unique doctor-patient dyad).

Methods: We collected interbeat interval responses (IBI) continuously during consultations between oncologists and patients undergoing cancer treatment ($N = 102$ unique doctor-patient interactions) at a hospital in Austria.

Results: Physiological linkage varied by an interaction between role (doctor vs. patient) and relationship length (in a non-linear, quadratic pattern). Patients showed significant positive linkage to their doctors (i.e., doctors' physiological responses positively, significantly predicted patients' responses) in relationships that spanned three to eight consultations together. Patients were not linked to their doctors in shorter or longer relationships. Doctors were never significantly linked to their patients, meaning that patients' physiological responses never predicted doctors' responses.

Conclusion: These results reveal that, by influencing patients' physiological responses on a moment-to-moment basis, doctors may have even more influence over patients' physiology than previously known.

1. Introduction

Influence is a hallmark of doctor-patient interactions. Numerous studies have shown that doctors and patients mutually influence each other's behaviors and subjective experiences while interacting (Charles et al., 1997; Cherry et al., 2018; Kennifer et al., 2009; Lown et al., 2009; Roberts and Aruguete, 2000), sometimes leading to behavioral and affective similarity between doctors and patients. For example, active involvement from doctors (e.g., providing information) is positively associated with active involvement from patients (e.g., expressing concerns) in a bidirectional relationship (Gordon et al., 2006; Street et al., 2007; Street and Millay, 2001). Doctors and patients also show similarity in subtle, nonverbal behaviors, such as head nodding and smiling (Duggan and Bradshaw, 2008). Even affective experiences—for example, satisfaction after a consultation—tend to be correlated between doctors and patients (McKinstry et al., 2006).

Recently, scholars have suggested that the physiological responses of doctors and patients may also become "synchronized" or similar to each other during interactions (Adler, 2002). Physiological synchronization can develop between people across a range of relationships and settings (reviews by Palumbo et al., 2017; Timmons et al., 2015). For example, parents and children (Waters et al., 2020), romantic couples (Helm et al., 2014), and psychotherapists and clients (Marci and Orr, 2006) have all shown correspondence in their autonomic nervous system

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https://doi.org/10.1016/j.socscimed.2021.114220
Received 12 January 2021; Received in revised form 3 July 2021; Accepted 9 July 2021
Available online 10 July 2021

(ANS) responses while interacting with each other. Importantly, researchers have suggested that physiological linkage may be one pathway through which social relationships influence health, as the physiological processes in one partner "transfer" to the other partner through social interaction (Adler, 2002; Butler, 2011). For example, mothers who have been stressed (while without their infants) then "transfer" their physiological stress responses to their infants when reunited with them (Waters et al., 2014).

In the current research, we test whether such physiological influence exists between oncologists and their patients by examining moment-to-moment physiological "linkage" of ANS responses during consultations. We operationalize physiological linkage as the extent to which the physiological response of one person—the "sender"—at one time interval predicts the physiological response of the other person—the "receiver"—at a subsequent time interval (Thorson et al., 2018). Because interactions between oncologists and their patients are frequently stressful and emotional (Brown et al., 2009; Schofield et al., 2003), this research is important for its potential to reveal the "transfer" or "contagion" of physiological responses that are associated with affective processes from one person to another in these settings. Furthermore, although researchers have speculated that this time-lagged type of physiological similarity might occur between doctors and patients (Adler, 2002), to our knowledge, no research has tested this.

Researchers have theorized that physiological linkage occurs when people are attentive to each other's behaviors and social cues during an interaction and experience physiological changes as a result. Supporting this perspective, physiological linkage of ANS responses has been tied to social processes that are associated with being attentive to others, including empathic accuracy (Brown et al., 2020) and group decision-making (Thorson et al., 2021). Furthermore, recent evidence has shown that physiological linkage occurs during times when partners are motivated to attend to each other. For example, while solving math problems together, women undergraduates in math—whose abilities in math were threatened—were physiologically linked to their female peers specifically when those peers provided information that could be helpful for solving the math problems (Thorson et al., 2019). In addition, during cross-race dyadic interactions, African Americans were physiologically linked to European Americans when they had particular reason to be attentive to those European Americans—when they were showing behavioral cues of anxiety (West et al., 2017).

According to this theoretical model of physiological linkage, during doctor-patient interactions, physiological linkage should occur when doctors and patients provide information regarding their own physiological and psychological experiences. This information could come through a variety of channels, such as behaviors, facial expressions, or speech (Cherry et al., 2018; Elliott et al., 2016; Kennifer et al., 2009; Roter et al., 2006). For example, a grimace from a patient might indicate that the patient is experiencing pain; a lack of eye contact from a doctor might indicate that the doctor is nervous. When the cues from the "sender" are noticed by the "receiver" (e.g., when a doctor notices that a patient feels anxious), physiological linkage may occur if the receiver then experiences a similar physiological response as the sender (e.g., if the doctor experiences a physiological response of anxiety as well).

Here, we examine whether physiological linkage occurs from doctors to patients (i.e., do the physiological responses of doctors predict the responses of patients?) and from patients to doctors (i.e., do the physiological responses of patients predict the responses of doctors? See Fig. 1). For several reasons, we predict that linkage from doctors to patients will be stronger than linkage from patients to doctors. First, within doctor-patient relationships, doctors tend to exert a more powerful influence on patients' behaviors and subjective experiences than vice versa (Menchik and Jin, 2014; Street and Buller, 1987), and patients tend to pay more attention to building a relationship with their doctor than the reverse (Siminoff et al., 2006).

Second, in general, people in low-power or low-status roles are more influenced by and pay more attention to those in high-power or high-status roles than vice versa (Blader et al., 2016; Fiske, 2010; Galinsky et al., 2006; Magee and Galinsky, 2008). Recent findings regarding physiological linkage show this pattern, too. For example, an experimental manipulation of status between strangers led low-status partners to show more linkage to high-status partners than vice versa (Kraus and Mendes, 2014). In the context of doctor-patient interactions, patients are both lower in status (because doctors have more domain-relevant-expertise and education than patients) and lower in power (because patients are dependent on doctors for diagnoses and treatment options). These hierarchical roles play out in doctor-patient behavior; for example, doctors use more technical and complex language (Tran and Sweeny, 2020), they ask more questions (Ohtaki et al., 2003), they use more directive statements (Ohtaki et al., 2003), they interrupt more (Ohtaki et al., 2003), and they even influence where

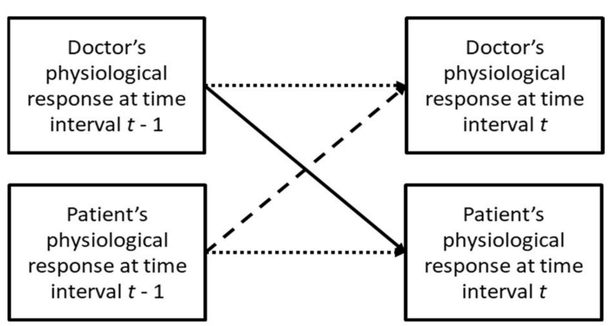


Fig. 1. Model Used to Assess Physiological Linkage. *Note.* The solid diagonal line represents physiological linkage for patients, where the physiological response of the doctor predicts the physiological response of the patient at a later time interval. The dashed diagonal line represents physiological linkage for doctors, where the physiological response of the patient predicts the physiological response of the doctor at a later time interval. The dotted horizontal lines represent stability for doctors and patients, where their own prior responses predict their responses at a later time interval.

Note. The solid diagonal line represents physiological linkage for patients, where the physiological response of the doctor predicts the physiological response of the patient at a later time interval. The dashed diagonal line represents physiological linkage for doctors, where the physiological response of the patient predicts the physiological response of the doctor at a later time interval. The dotted horizontal lines represent stability for doctors and patients, where their own prior responses predict their responses at a later time interval.

patients look (Montague and Asan, 2014). Taken together, this research suggests that patients will show physiological linkage to doctors (i.e., that doctors' physiological responses will predict the responses of patients) more than vice versa.

In addition to examining how role (i.e., whether one is a doctor or a patient) shapes physiological linkage during doctor-patient interactions, we also examine one critical factor that can affect doctor-patient interactions: the length of the doctor-patient relationship (also known as the continuity of care between doctor and patient). Because we study interactions structured around the management of chronic illness—between oncologists and patients undergoing cancer treatment—repeated interactions occur between the same doctor and patient, making it possible for interpersonal dynamics between doctors and patients to change over the course of these interactions. Indeed, past research has shown that patients' positive affective experiences related to their doctor (such as feelings of trust and satisfaction) usually increase the longer that doctors and patients have known each other (Adler et al., 2010; Pollak et al., 2010) and that patients prefer to have providers they know well, particularly in oncology (Baker et al., 2003; Snyder et al., 2007). In addition, doctors often influence the behavior of patients more in longer-term relationships: for example, patients who have doctors engaged in patient-centered behavior tend to disclose more to their doctors the longer they have known them (Wissow et al., 2003). Potentially as a result of these interpersonal dynamics, longer-term relationships between doctors and patients are also associated with better health outcomes, including less frequent hospitalization and lower mortality rates (Pereira Gray et al., 2018; Walraven et al., 2010).

We predict that relationship length (measured as the number of consultations doctors and patients have had with each other) influences the amount of physiological linkage between doctors and patients. Although relationship length has been tied to other psychosocial processes during doctor-patient interaction, to our knowledge, no prior work has examined its association with physiological similarity between doctors and patients. We test linear and non-linear trends in the association between linkage and relationship length for two reasons. One, in general, relationship processes and outcomes rarely follow linear trends (Butler, 2011; Girme, 2020). Two, there is evidence to suggest that aspects of doctor-patient interactions specifically—like patient satisfaction—change over the course of doctor-patient relationships in a non-linear, quadratic fashion, increasing initially, but then stabilizing or declining as time goes on (Donahue et al., 2005; Frederiksen et al., 2009). One reason for this may be that patients expect doctors to know them better as time goes on; although increased familiarity develops initially, it often does not improve past a certain point. If doctors do not continue to get to know patients better, this can cause feelings, like patient satisfaction, to decrease (Frederiksen et al., 2009). In a similar manner, it is possible that psychosocial processes associated with linkage, like attention to or engagement with another person (which can change over the course of doctor-patient relationships; Love et al., 2000; Mathews et al., 2016), might also change in a non-linear, quadratic fashion.

2. Research overview

We examined the ANS activity of oncologists and their patients during a consultation in which doctors and patients discussed patients' most recent computerized tomography (CT) scan. Doctors and patients were matched for consultations based on the availability of doctors at the time of patients' scans; neither doctors nor patients had any choice in who they met with. We continuously measured interbeat intervals (IBI; the time interval between subsequent heartbeats) in doctors and patients during the consultation. Interbeat intervals are influenced by both the sympathetic and parasympathetic nervous systems, and they change relatively quickly in response to changes in affective states (Mendes, 2016). To measure relationship length, we examined patient records to figure out the number of consultations that the same doctor and patient had together. We obtained data from consultations between 102 unique doctor-patient dyads.

We estimate physiological linkage as the extent to which the physiological response of one person at one time interval predicts the physiological response of the other person at a subsequent time interval (Thorson et al., 2018; see Fig. 1) for three reasons. One, researchers have theorized that the time-lagged element of linkage allows for an understanding of the extent to which doctors and patients might be attentive to each other's behaviors and social cues during an interaction and experiencing physiological changes as a result (Thorson et al., 2018, 2019). Two, this approach allows us to examine factors that affect the degree to which people show physiological linkage to each other: here, people's role (doctor versus patient) and the length of the relationship for each doctor-patient dyad. Third and finally, this approach adjusts for physiological stability (i.e., how much people's physiological responses are predicted by their own prior responses; see Fig. 1), which is important given that stability accounts for a large share of the variance in people's physiological responses (Thorson et al., 2018; Thorson and West, 2018). Because IBI provides a measure of general autonomic arousal and the intensity of people's experiences, we view physiological linkage of IBI responses as indicating how much individuals track changes in the intensity of their partners' psychological states.

3. Methods

3.1. Participants

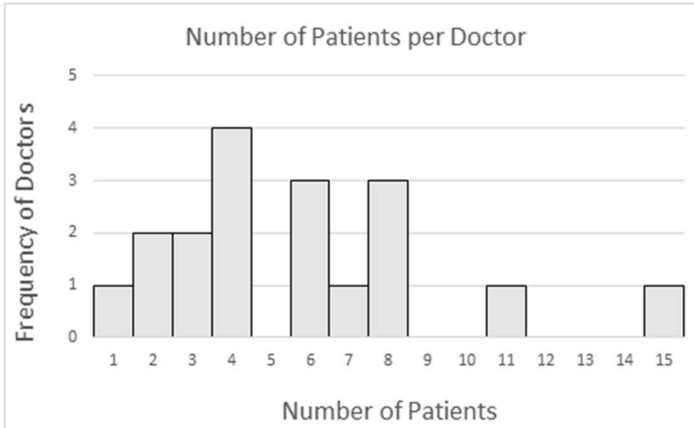
Participants were recruited from the oncology unit of University Hospital Graz in Austria. Inclusion criteria included fluency in German or English and being 60 years of age or younger, given age-related differences in ANS activity (Lipsitz and Novak, 2013). Exclusion criteria included a diagnosis of cardiovascular disease, diabetes, or pregnancy. We selected eligible patients from a database of patients at the oncology unit and sent them an informational recruitment letter. We also called the patients a few days later to ask if they were interested and had any questions. Interested patients participated during the consultation that followed their next computerized tomography (CT) scan. During a weekly doctors' meeting, we also presented information about the study to eligible doctors. Only doctor-patient dyads in which both the doctor and patient indicated interest in the study were enrolled in the study.

Doctors and patients were matched for consultations based on which doctor was available in the hospital at the time of the patient's appointment. Patients did not select a particular doctor when making an appointment, nor did they know ahead of the appointment with whom they would be meeting. Between April 2017, and March 2018, we recruited and collected data from 150 patients and 18 doctors.

The data from 48 doctor-patient combinations were excluded because there were excessive artifacts in the physiological data (see below), we experienced technical problems obtaining the data, or the doctor-patient consultations lasted fewer than 5 min. The final dataset includes 18 doctors (*M* age = 41.06, *SD* age = 7.83; 61.1% male; 38.9% female; 100% White European) and 102 patients (*M* age = 52.12, *SD* age = 6.42; 39.2% male; 60.8% female; 99% White European, 1% Asian), yielding data for 102 unique doctor-patient dyads (see Fig. 2). The number of patients each doctor saw did not predict the relationship length associated with each of the doctor's interactions ($b = -0.08$, $SE = 0.09$, $t(6.59) = -0.91$, $p = .40$); in other words, there was no association between how many patients a doctor saw and the length of patient relationships that doctor had.

3.2. Procedure

Prior to consultations, participants were fitted with an ECG Holter monitor (Schiller Holter MedilogAR). Three Ag/AgCl electrodes were placed on the distal end of the right clavicle, lower left rib cage chest, and lower abdomen. We used electrocardiography (ECG) to



Note. Each bar indicates the frequency of doctors who had a certain number of patients (e.g., two doctors had three patients in the sample).

Fig. 2. Number of Patients per Doctor. *Note.* Each bar indicates the frequency of doctors who had a certain number of patients (e.g., two doctors had three patients in the sample).

continuously and simultaneously record ANS responses from both patients and doctors during the consultation. The consultations ranged between five and 33 min. Doctors and patients discussed results from patients' recent CT scan, assessed the efficacy of the current treatment, and considered the patient's prognosis. Both doctors and patients were seated during the interactions. Doctors completed a demographics questionnaire upon enrolling in the study, and patients completed this questionnaire after their consultation. The ethics committee of the Medical University of Graz approved the study. Participants provided informed consent prior to data collection.

3.3. Measures

3.3.1. Interbeat interval responses

Data were sampled at a rate of 1000 Hz. We analyzed the ECG data with Kubios HRV Premium software version 3.3.1 (Tarvainen et al., 2014) in 1-min intervals. Visual artifacts correction was performed on the IBI series, and, if needed, an automatic correction algorithm was applied. Intervals containing more than 5% of artifacts or excessive ectopic beats were excluded. In total, 12.6% of IBI responses were marked as missing. (See the Supplemental Material for an analysis examining likelihood of missingness by role and relationship length. We also include a version of our primary analysis conducted with maximum likelihood estimation to account for missing data, which shows results consistent with those presented below.)

We person-centered IBI responses within each participant and within each interaction (i.e., we subtracted the average IBI response per participant per interaction from each of their IBI responses throughout the interaction). Thus, higher values for each participant represent a higher-than-average response for that participant within that interaction (see Thorson et al., 2018 for a discussion of this approach). We did person-centered responses to account for individual differences present in participants' ANS responses (Berntson et al., 1994) given that they are largely influenced by individual differences, such as genetics, health, and lifestyle (de Geus et al., 2015; Hu et al., 2017).

3.3.2. Relationship length

We measured the number of times that a patient had met with a particular doctor via patient records ($M = 3.5$, $SD = 2.8$). The minimum relationship length was one consultation, meaning that the consultation during which we measured physiological responses was the first consultation between a particular patient and doctor. The maximum relationship length was twelve consultations.

3.3.3. Covariates

In a sensitivity analysis, we examined whether effects were robust when adjusting for gender, age, smoking status, and exercise status, all of which can influence ANS activity (Dart et al., 2002; Hu et al., 2017; Lipsitz and Novak, 2013). We also adjusted for patients' cancer stage, the valence of news provided in the consultation, and the number of minutes for which we had receiver physiological data, all of which could potentially vary by relationship length, and cancer type.

3.3.4. Smoking status

Participants identified as ex-smokers (5.6% of doctors; 25.5% of patients), smokers (27.8% of doctors; 24.5% of patients), or non-smokers (66.7% of doctors; 50.0% of patients).

3.3.5. Exercise status

Participants answered the following questions: "During a normal week, do you practice regular physical activity (e.g. brisk walking, jogging, cycling) long enough to work up a sweat? If yes, how many hours on average per week?" We categorized participants' answers as no exercise at all (16.7% of doctors; 53.9% of patients), fewer than 3 h weekly (44.4% of doctors; 0% of patients), between 3 and 6 h weekly (27.8% of doctors; 26.5% of patients), more than 6 h weekly (11.1% of doctors; 19.6% of patients).

3.3.6. Cancer stage

Patients' cancer stages were classified as follows: stage 1 (44.1%), stage 2 (4.9%), stage 3 (17.6%), and stage 4 (33.3%).

3.3.7. News valence

Doctors classified the news delivered in the consultation as bad (11.8%), good (52.9%), or neutral (32.4%; 2.9% missing data).

3.3.8. Cancer type

Doctors classified patients' cancer types as follows: colorectal (46.1%), breast (39.2%), pancreatic (8.8%), lung (3.9%), and prostate (2%). These rates differ from total rates of cancers in Austria (colorectal: 6.0%, breast: 12.3%, pancreatic: 4.2%, lung: 10.9%; prostate: 12.6%; The Global Cancer Observatory, 2021), likely for three reasons: 1) we restricted patients' age (between 18 and 60 years) which could result in a greater prevalence of colorectal, breast, and pancreatic cancers and a lower prevalence of prostate and lung cancers, 2) we conducted our research at a general oncology unit, which treats the most common types of cancer (five out of the six most common types of cancer are represented here) as opposed to a specialty unit focused on rarer cancer types, and 3) we had a slightly higher percentage of females (60.8%) relative to males (39.2%) in our sample, which could result in breast cancer rates being higher and prostate cancer rates being lower than rates in the general population.

4. Results

Additional analytic details and results are provided in the Supplemental Material (SM). At the request of doctors who participated in the study, all participants were told that raw data would remain confidential and would not be shared; however, the analysis syntax for all models is available at https://osf.io/cpejn/?view_only=7c348bf999954f21befcd989f8b15dad.

We estimated a version of the stability and influence model, based on the Actor-Partner Interdependence Model (Kenny et al., 2006), to examine physiological linkage (Thorson et al., 2018). We predicted participants' IBI response during 1 min from the IBI response of their partner (the "sender") during the prior minute to yield an estimate of physiological linkage (the fixed effect component from coefficient b_{2ijk} in Equation (1)). We adjusted for participants' own IBI responses (the "receiver's" responses) from the prior minute, which yielded an estimate of physiological stability (the fixed effect component from coefficient b_{1ijk}). We examined whether linkage and stability paths varied by role (doctor vs. patient) and by relationship length (mean-centered). To examine whether relationship length had a nonlinear effect on physiological linkage, we included a quadratic term for relationship length as well. Equation (1) provides the Level 1 equation for person i in dyad j with (or for) doctor k at time t (see also Table 1). We used multilevel modeling with PROC MIXED in SAS 9.4 to adjust for nonindependence in responses between patients of the same doctor and between the same doctors (similar to the reciprocal one-with-many-design with indistinguishable partners described in Kenny and Kashy, 2011; Hagiwara et al., 2014), between members of the same doctor-patient dyad, and across time. We describe the covariance parameters we used to accomplish these adjustments and their results in the online supplemental materials.

$$
\begin{aligned}
Y_{ijkt} = {} & b_{0ijk} + b_{1ijk} \times ReceiverIBI_{ijk(t-1)} + b_{2ijk} \times SenderIBIi_{jk(t-1)} + \\
& b_{3ijk} \times Role_{ijk} + b_{4ijk} \times Roleijk \times ReceiverIBI_{ijk(t-1)} + b_{5ijk} \times Role_{ijk} \times SenderIBI_{ijk(t-1)} + \\
& b_{6ijk} \times Length_{jk} + b_{7ijk} \times Length_{jk} \times ReceiverIBI_{ijk(t-1)} + b_{8ijk} \times Length_{jk} \times SenderIBI_{ijk(t-1)} + \\
& b_{9ijk} \times Length_{jk} \times Role_{ijk} + b10ijk \times Length_{jk} \times Role_{ijk} \times ReceiverIBI_{ijk(t-1)} + \\
& b_{11ijk} \times Length_{jk} \times Role_{ijk} \times SenderIBI_{ijk(t-1)} + \\
& b_{12ijk} \times Length_{jk} \times Length_{jk} + b_{13ijk} \times Length_{jk} \times Length_{jk} \times ReceiverIBI_{ijk(t-1)} + \\
& b_{14ijk} \times Length_{jk} \times Length_{jk} \times SenderIBI_{ijk(t-1)} + \\
& b_{15ijk} \times Length_{jk} \times Length_{jk} \times Role_{ijk} + b_{16ijk} \times Length_{jk} \times Length_{jk} \times Role_{ijk} \times ReceiverIBI_{ijk(t-1)} + \\
& b_{17ijk} \times Length_{jk} \times Length_{jk} \times Role_{ijk} \times SenderIBI_{ijk(t-1)} + e_{ijt}
\end{aligned}
\tag{1}
$$

Table 2 shows results for the physiological linkage paths; results for the physiological stability paths are in the online supplemental materials. We report effect sizes as partial-R^2s (Edwards et al., 2008). There was no main effect of senders' prior physiological responses on receivers' current physiological responses, meaning that, on average, there was no significant linkage, $b = 0.05$, $p = .17$, $R^2 = 0.02$. However, there was a significant two-way interaction between senders' prior physiological responses and role, indicating that among all participants, linkage varied as a function of role, $b = 0.13$, $p < .001$, $R^2 = 0.15$. We also found a significant two-way interaction between senders' prior physiological responses and relationship length, indicating that among all participants, linkage varied as a function of relationship length, $b = 0.03$, $p = .02$, $R^2 = 0.06$. These interactions were qualified by a significant three-way interaction between senders' prior physiological responses, role, and relationship length, indicating that the association between linkage and relationship length varied as a function of role, $b = 0.04$, $p = .003$, $R^2 = 0.10$.

Additional results suggested that the association between linkage and relationship length was non-linear. Specifically, a marginally significant two-way interaction between senders' prior physiological responses and the quadratic term for relationship length indicated that there was a quadratic association between linkage and relationship length, $b = -0.005$, $p = .06$, $R^2 = 0.03$. This interaction was qualified by the hypothesized three-way interaction between senders' prior physiological responses, the quadratic term for relationship length, and role, indicating that the non-linear (quadratic) association between linkage and relationship length varied as a function of role, $b = -0.01$, $p = .005$, $R^2 = 0.07$.

Next, we investigated this three-way interaction. For patients, we found that the two-way interaction between senders' prior physiological responses and the quadratic term for relationship length was significant, indicating that there was a non-linear association between linkage and relationship length for patients, $b = -0.01$, $SE = 0.004$, $t(77.6) = -3.27$, $p = .002$, 95% CI: -0.02 to -0.006, $R^2 = 0.12$ (see Fig. 3). For doctors, the two-way interaction between senders' prior physiological responses and the quadratic term for relationship length was not significant, indicating that there was not a non-linear association between linkage and relationship length for doctors, $b = 0.003$, $SE = 0.004$, $t(97.1) = 0.87$, $p = .39$, 95% CI: -0.005 to 0.01, $R^2 = 0.01$. (In addition, for doctors, the two-way interaction between senders' prior physiological responses and the linear term for relationship length was not significant, indicating that there was neither a non-linear, nor linear, association between linkage and relationship length for doctors, $b = -0.01$, $SE = 0.02$, $t(67.1) = -0.61$, $p = .54$, 95% CI: -0.04 to 0.02, $R^2 = 0.01$).

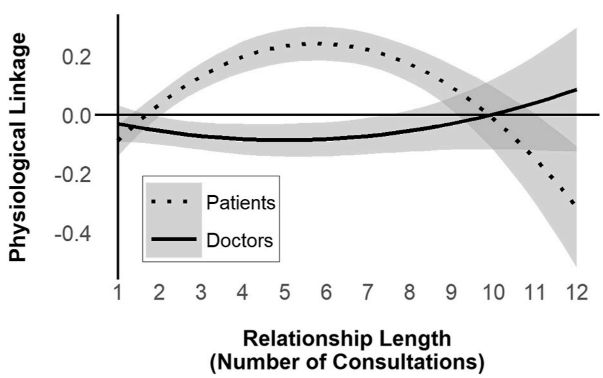
As shown in Fig. 3 and in Table 3, for patients who were in their first or second consultation with their doctors, there was no main effect of senders' (i.e., doctors') prior physiological responses on patients' current physiological responses, meaning that patients did not show significant linkage to their doctors. However, for patients who were in their third to eighth consultation with their doctors, there was a main effect of senders' (i.e., doctors') prior physiological responses on patients' current physiological responses, meaning that patients showed significant linkage to their doctors. Finally, for patients who were in their ninth to twelfth consultation with their doctors, there was no longer a significant effect of senders' (i.e., doctors') prior physiological responses on

Table 1
Variables in Equation (1).

Term	Description
ReceiverIBI	Receiver IBI response, person-centered
SenderIBI	Sender IBI response, person-centered
Role	Role (doctor [coded as −1) or patient [coded as 1])
Length	Relationship length, mean-centered

Table 2
Parameter estimates for physiological linkage main effect and interactions.

Fixed Effect	Fixed effect component of this coefficient from Equation 1	Question Addressed by Fixed Effect	*b*	*SE*	*t*	*df*	*p*	95% CI	Partial R^2
Main effect of Sender $IBI_{(t-1)}$	b_{2ijk}	Is there a main effect of linkage?	0.05	0.03	1.38	77	.17	-.02 to 0.11	0.02
Interaction between Sender $IBI_{(t-1)}$ and Role	b_{5ijk}	Does linkage differ by role?	0.13	0.04	3.47	70.3	.001	0.05 to 0.20	0.15
Interaction between Sender $IBI_{(t-1)}$ and Relationship Length	b_{8ijk}	Does linkage differ by relationship length?	0.03	0.01	2.37	85.8	.02	0.004 to 0.05	0.06
Interaction between Sender $IBI_{(t-1)}$, Relationship Length, and Role	b_{11ijk}	Does the association between linkage and relationship length vary as a function of role?	0.04	0.01	3.05	82	.003	0.01 to 0.06	0.10
Interaction between Sender $IBI_{(t-1)}$ and quadratic term for Relationship Length	b_{14ijk}	Does linkage differ by relationship length in a non-linear (quadratic) pattern?	−0.005	0.003	−1.87	119	.06	−0.01 to 0.0003	0.03
Interaction between Sender $IBI_{(t-1)}$, quadratic term for Relationship Length, and Role	b_{17ijk}	Does the non-linear (quadratic) association between linkage and relationship length vary as a function of role?	−0.01	0.003	−2.90	114	.005	−0.02 to −0.003	0.07



Note. Gray bands indicate standard errors.

Fig. 3. Physiological Linkage between Doctors and Patients as a Function of Relationship Length. *Note.* Gray bands indicate standard errors.

patients' current physiological responses, meaning that patients no longer showed linkage to their doctors. Doctors never showed significant linkage to patients, regardless of how many consultations they had with those patients.

4.1. Sensitivity analyses

In one sensitivity analysis, we examined whether there were any higher-order (i.e., cubic) non-linear effects of relationship length on physiological linkage. We did not find any interactions between senders' prior physiological responses and a cubic term for relationship length (see the online supplemental materials for results). Combined with our results above, this analysis provides additional evidence that the association between physiological linkage and relationship length—at least within relationships lasting one to twelve consultations—is a quadratic one.

In a second sensitivity analysis, we examined whether effects were robust when adjusting for receivers' gender, age, smoking status, and exercise status, as well as patients' cancer stage, the valence of the news presented during the consultation, the length of the consultation, and patients' cancer type. When including these covariates, all results are consistent with the ones presented above (see the online supplemental materials for results).

5. Discussion

Do doctors and patients exhibit similarity in their physiological responses during interactions with one another? We found that they do. During consultations between oncologists and their patients, we found that patients showed physiological linkage of ANS responses to their doctors—meaning that doctors' physiological responses positively predicted patients' responses at a subsequent time interval (see Table 2). We also found that this linkage varied as a function of how long doctors and patients had known each other: patients only showed linkage to their doctors when doctors and patients had a total of three to eight

Table 3
Parameter estimates for physiological linkage main effect for patients and doctors at different relationship lengths.

Relationship Length (Number of Consultations between Doctor and Patient, including Current Consultation)	Main Effect of Sender $IBI_{(t-1)}$ for Patients (i.e., Do patients show significant linkage to doctors?)				Main Effect of Sender $IBI_{(t-1)}$ for Doctors (i.e., Do doctors show significant linkage to patients?)				Interaction between Sender $IBI_{(t-1)}$ and role (i.e. Does linkage differ by role?)			
	b	*SE*	*p*	Partial R^2	*b*	*SE*	*p*	Partial R^2	*b*	*SE*	*p*	Partial R^2
1	−0.09	0.05	.10	0.05	−0.03	0.06	.63	0.01	−0.03	0.04	.49	0.01
2	0.04	0.04	.37	0.02	−0.05	0.05	.26	0.04	0.05	0.03	.16	0.03
3	0.13	0.04	.005	0.13	−0.07	0.05	.14	0.07	0.10	0.03	.003	0.13
4	0.20	0.05	<.001	0.19	−0.08	0.05	.12	0.06	0.14	0.04	<.001	0.16
5	0.23	0.06	<.001	0.22	−0.09	0.06	.13	0.05	0.16	0.04	<.001	0.17
6	0.24	0.06	<.001	0.26	−0.08	0.06	.16	0.05	0.16	0.04	<.001	0.18
7	0.22	0.06	<.001	0.27	−0.07	0.06	.25	0.03	0.15	0.04	.001	0.16
8	0.17	0.06	.007	0.18	−0.05	0.07	.44	0.01	0.11	0.05	.02	0.08
9	0.09	0.08	.23	0.03	−0.03	0.09	.74	<0.01	0.06	0.06	.31	0.01
10	−0.01	0.11	.91	0.00	0.00	0.12	.99	<0.01	−0.01	0.08	.93	0.00
11	−0.15	0.15	.33	0.02	0.04	0.16	.80	<0.01	−0.09	0.11	.40	0.01
12	−0.31	0.21	.13	0.03	0.09	0.21	.68	<0.01	−0.20	0.15	.19	0.02

consultations together; in shorter and longer relationships, patients were not physiologically linked to doctors (see Table 3 and Fig. 3). Doctors never experienced physiological linkage to their patients, meaning that the physiological responses of patients never predicted the responses of doctors (see Table 3 and Fig. 3).

The current research may have implications for the influence of doctor-patient interactions on patient physiology and health by revealing that, on a moment-to-moment basis, doctors influence the physiological responses of their patients during interactions with them. Imagine an oncologist who is calm throughout an interaction, despite her patient being distressed and the content of the discussion being negative (e.g., a negative test result). If the patient is physiologically linked to the doctor, and the doctor "transfers" her experience of calm to her patient, successful downregulation of her patients' stress responses could directly benefit the patient's health (Juster et al., 2010). Indirect consequences of feeling less stressed, such as greater treatment adherence, might also positively influence the patient's health (DiMatteo and Haskard-Zolnierek, 2010). Conversely, an oncologist who is stressed during an interaction and then transfers that experience to her patient could create or exacerbate the responding of stress-related biological systems, potentially harming her patient's health. As we mention below, future research should try to address the types of physiological responses that doctors pass on to patients and what the outcomes of this linkage are. At this point, the idea that physiological linkage from doctors to patients could contribute to patient health or other outcomes of healthcare is speculative. Nevertheless, these results may make an important step in understanding the outcomes of doctor-patient interactions for health by showing that, during real interactions, doctors influence the physiological responses of their patients.

Given that physiological linkage has theoretically and empirically been tied to psychosocial processes involving attention to others, these data suggest that cancer patients may be particularly attentive to oncologists whom they have known for a couple of consultations. Perhaps patients need a few consultations to become comfortable with their doctors (Pandhi et al., 2007); after that point, they may become better at tuning in to and understanding the different cues that their doctors present (Thomas and Fletcher, 2003), leading to more linkage. In addition, because doctors feel more comfortable with and responsible for patients after more consultations (Blankfield et al., 1990; Hjortdahl, 1992), these feelings may allow doctors to be more expressive in their speech and behaviors (Human and Biesanz, 2013), which could also potentiate linkage from doctors to patients (Thorson et al., 2018).

One question our data raise is why linkage from doctors to patients is non-existent for patients in longer-term relationships. If patients expect their relationships to become closer with doctors the longer they have known them and this closeness does not develop, then the quality of the relationship—and potentially attention and physiological linkage—could decline (Frederiksen et al., 2009). Alternatively, given that less attention is often paid to what is familiar (Gobbini and Haxby, 2006), it is possible that patients pay less attention to their doctors once they feel familiar and have established routines for their appointments, which might also cause linkage to decline. There is greater variability in linkage in longer-term relationships (see Table 3 and Fig. 3), suggesting that there may be factors in longer-term relationships that predict whether linkage increases, remains stable, or decreases—for example, the success of the current treatment—and future research might examine some of these factors.

One strength of this study is that doctors and patients were matched for consultations based only on the availability of doctors after patients' scans, meaning that doctors and patients had no choice regarding who they met with. Thus, the non-linear effects of relationship length that we observed are not due to personal preference or liking between specific doctor-patient dyads. To our knowledge, this is relatively rare in the literature on continuity of care (Adler et al., 2010) and represents an important step in identifying the causal direction between continuity of care and patient experiences.

These data highlight the need to consider non-linear trajectories of patient experiences over time. Close relationships such as those between doctors and patients rarely follow linear patterns over time (Girme, 2020), and understanding how different aspects of patient experiences (such as their physiological responses) change over time could prove useful for improving doctor-patient communication. For example, perhaps doctors and patients need help communicating and connecting with each other in longer-term relationships. Models that only consider linear changes in patient experiences might miss recognizing these opportunities for intervention.

5.1. Future directions and limitations

We have speculated, based on prior evidence, that patients' attention to their doctors may facilitate linkage. Future research might capture other measures of attention and engagement from patients, such as memory for information provided during the consultation (Kessels, 2003), as well as the behavioral cues provided by doctors, which might influence the strength of linkage from doctors to patients (e.g., perhaps patients are more linked to their doctors when those doctors are more expressive with their faces; Roter et al., 2006). Understanding which aspects of doctor-patient interactions are associated with linkage would help us better understand why linkage occurs and potentially illuminate targets for improving doctor-patient communication.

Relatedly, an important question regarding this research is what the consequences are of linkage in this context. For example, are patients more satisfied or are they more likely to adhere to treatment plans if they are more physiologically linked to their doctors? Physiological linkage is neither unilaterally good nor bad for relationships; rather, the outcomes depend on the social context, the physiological response being studied, and the reasons linkage has occurred (Danyluck and Page-Gould, 2018; Timmons et al., 2015). If future research shows that linkage is tied to important outcomes in doctor-patient relationships during cancer treatment, then linkage could provide an extremely useful tool—because it can be collected unobtrusively in social interactions and does not rely on self-report—in identifying which relationships may need changes to facilitate better outcomes.

We examined how relationship length affected linkage for different doctor-patient dyads who were each measured at one relationship length in time (for example, Dyad A at their first consultation but Dyad B at their tenth consultation; a between-dyads approach), which allowed a greater sample size of unique doctor-patient dyads. Future research might complement the current work by addressing how relationship length moderates linkage for the same doctor-patient dyads who are measured at multiple relationship lengths in time (for example, Dyads A and B measured ten times each, during their first through tenth consultations; a within-dyads approach; Bolger and Zee, 2019). This procedure could elucidate the degree of heterogeneity in how linkage shifts over time and uncover variables that explain this heterogeneity. For example, perhaps patients in some dyads continue to increase in linkage over time, while others increase but then decrease again.

We studied high-stakes, real interactions between doctors and patients who were discussing patients' prognoses for a potentially terminal illness; specific features of this context could influence our findings in ways that are distinct from other doctor-patient interactions. For instance, medical interactions that involve less stress and uncertainty (e.g., routine primary care appointments) may involve less attention from patient to doctor, resulting in reduced linkage. Additionally, interactions in which doctors are trying to obtain information from patients—for example, to assess pain (Ruben et al., 2015)—might involve more attention from doctors to patients, potentially resulting in physiological linkage from patients to doctors (or bi-directional linkage patterns). Future research might examine what features of doctor-patient interactions contribute to linkage and what the outcomes are of linkage in different doctor-patient contexts.

Our sample size for research on physiological linkage and doctor-patient interactions in real-life contexts is quite high. However, consistent with the city and hospital in which we conducted this work, our sample was highly homogenous in terms of race and racial concordance between doctors and patients, which are important predictors of psychosocial processes in doctor-patient interactions (Hagiwara et al., 2013; Penner et al., 2016). As a result, linkage in cross-race interactions might be different as well (West et al., 2017), and we hope that future work will address how race and racial concordance within doctor-patient dyads influences physiological linkage.

6. Conclusion

The current study demonstrates that influence from doctors to patients can occur physiologically from minute to minute during real-life, high-stakes consultations in oncology. Although we found that doctors' physiological responses were never predicted by the prior responses of patients, patients' physiological responses were positively and significantly predicted by the prior physiological responses of doctors when their relationships spanned three to eight consultations. These results suggest that psychological processes associated with linkage, such as engagement with others, can change over the course of doctor-patient relationships, and they highlight the need to examine non-linear trajectories of patient experiences over time. Importantly, these results also reveal that, by influencing patients' physiological responses on a moment-to-moment basis, doctors may have even more influence over patients' physiology—and potentially their health—than previously known.

Credit author statement

Marta Vigier: Conceptualization, Methodology, Project administration, Investigation, Data curation, Writing – original draft. Katherine R. Thorson: Conceptualization, Formal analysis, Resources, Data curation, Visualization, Writing – original draft. Elisabeth Andritsch: Supervision, Resources. Herbert Stoeger: Resources. Leonie Suerth: Investigation. Clemens Farkas: Resources. Andreas R. Schwerdtfeger: Supervision, Writing – review & editing, Resources

Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2021.114220.

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