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BERTRAM GAWRONSKI

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CHAPTER TWO

Affect contagion: Physiologic covariation and linkage offer insight into socially shared thoughts, emotions, and experiences

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Abstract

Emotions, thoughts, and intentions are not simply concepts that live privately in our minds, but rather, affective states emanate from us via multiple channels—voice, posture, facial expressions, and behavior—and can influence those around us. *Affect contagion*, or the spread of affective states from one person to another, is studied in a variety of ways in the social sciences: sociologists study how happiness is contagious within social networks, social psychologists examine how imitation of affective states influences how we perceive others, and neuroscientists show that observing someone experience pain produces similar neural activation as experiencing the same pain.

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In this chapter, we present a theory of affect contagion that identifies processes, antecedents, moderators, and consequences. Using peripheral psychophysiology coupled with dyadic data modeling, we review a series of studies exploring social and personality factors that facilitate (or attenuate) affect contagion, specifically *closeness, group similarity, status, arousal,* and *valence*. We then extend the question of how situational and personal factors contribute to affect contagion, to speculate on possible social and behavioral consequences such as mutual trust and cooperative performance. Collectively this work has the potential to illuminate the antecedents of affect contagion, and the behavioral consequences for individuals and groups.

1. Introduction

Social psychology often examines processes within a social context using imagined others, photos and videos of people, or trained confederates to behave consistently across different interaction partners. While this work offers insight into many topics that social psychologists care about, such as stereotyping and biases, attitudes and beliefs, person perception, and emotional and motivational responses to others, this research cannot fully capture the unique and nuanced reciprocal interactions that occur in dynamic, face-to-face interactions between two or more people. Capturing processes that occur between two (or more) people allows for the examination beyond individual level responses and extends to actor effects (how our own predictors, such as our personality or traits, predict our outcomes), partner effects (how our partner's predictors, such as their personality or traits, predict our outcomes), and their interaction (Kenny, Kashy, & Cook, 2006).

While examining two or more subjects in real-time has a long history in psychology, this work has often relied on behavioral indicators or self-reported responses to assess reactions of dyadic and group interactions (Shelton, West, & Trail, 2010; West, Pearson, Dovidio, Shelton, & Trail, 2009; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). However, the value of dyadic processes rests on the dynamic processes—the ebb and flow between people that occurs during a social interaction—that benefits from continuous, on-line measurements of affective responses that do not interfere with the social interaction. Physiologic responses can provide these types of measures, given they are measured continuously and unobtrusively over time, and are associated with affective states (Thorson, West, & Mendes, 2018). These measures also allow for the examination of individual, dyadic, and group predictors.

Here, we propose a theory of *affect contagion* that relies on physiologic synchrony as a primary window into studying shared social experiences. In this chapter, we outline the antecedents of physiologic synchrony, distinct types of synchrony, processes that facilitate and attenuate synchrony, propose analytic strategies, identify context and moderators, and describe possible consequences. We review empirical studies demonstrating support for this model and propose new directions for this nascent work.

1.1 Mimicry of facial expressions

Modern social psychology has approached the question of how people share emotional states with each other via several distinct research approaches. Mimicry, or the mirroring of a partner's behavior, language, or expressions, is argued to be intimately related to affiliation processes. In studies using confederates, participants like confederates more, the more those confederates mimicked their behaviors (Lakin, Jefferis, Cheng, & Chartrand, 2003). Moreover, when individuals liked the confederate they were more likely to mimic specific behaviors (like touching their face or playing with their hair; (Hove & Risen, 2009). These studies highlight the importance of mimicry for facilitating positive social encounters (see Chartrand & Van Baaren, 2009, for a review).

Mimicry of facial expressions initially was argued to be an automatic and effortless process. For example, upon presentation of photos of smiling individuals, activation of the zygomaticus major muscles (cheek muscles implicated in smiling) was detected within 500 ms of stimulus onset, a duration presumed to be outside of conscious awareness (Dimberg & Thunberg, 1998). Across the lifespan, there is evidence of mimicry of facial expressions. Infants less than 3 days old will mirror facial actions—head movements, tongue protrusions—of an experimenter, suggesting biological preparedness to imitate others (Meltzoff & Moore, 1989). At the other end of the life span, long-married couples show similar expression lines presumably from years of repeated mimicry of expressions (Zajonc, Adelmann, Murphy, & Niedenthal, 1987). However, there is emerging evidence that highlights the importance of persons and situations in modulating facial mimicry; factors such as attachment style, empathy, and cognitive load can alter the degree to which we mimic others' facial expressions (Seibt, Mühlberger, Likowski, & Weyers, 2015).

Importantly, facial expressions are an imperfect measure of emotional states (Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019) and lack reliability, specificity, and generalizability. Additionally, emotions represent a narrow range of experiences, typically defined as short-lived, punctate experiences (Levenson, 2011). Affective states, on the other hand, provide a broader conceptual category that encompasses stress, motivation, evaluation, mood, and emotional experiences (Gross & Barrett, 2013). Affect contagion, then, is a concept that refers to the transmission and detection of affective states from one person (or persons) to another person (or persons). We next examine how affect contagion can be assessed and the various ways that signals are transmitted and detected between human and non-human animals.

1.2 Synchrony

Behavioral synchrony—mirrored behavior—can be observed throughout the animal kingdom. Frogs croak, crickets chirp, and birds sing in unison as a way to signal social information (Strogatz, 2003). This type of social signaling is observed spontaneously; fireflies captured from different regions and then released in the same location will blink intermittently and sporadically for a few minutes until the possi blinks in unison (Strogatz, 2003). Humans evidence synchrony across several domains. For example, females living in close proximity can develop coordinated menstrual cycles (McClintock, 1971), parents' oxytocin levels are synchronized to their infants' social engagement and coordination (Feldman, Gordon, & Zagoory-Sharon, 2011), and Eastern European audiences will clap spontaneously and in unison to express their appreciation for a performance (Néda, Ravasz, Brechet, Vicsek, & Barabási, 2000).

Behavioral synchrony requires a signal that can be transmitted, perceived, and then displayed across two or more people. This signal can be in the form of sensory output like facial expressions, movement, eye gaze, and voice. Human and non-human animal research suggests that behavioral synchrony likely occurs through mimicry, with conspecifics mimicking the behavior, affect, and actions of each other (Cheng & Chartrand, 2003; Ekman & Friesen, 1975; Lakin et al., 2003).

Importantly, synchrony can occur within relatively short periods of time, especially when signals are relatively easy to transmit and detect. An early example of voice synchrony demonstrated how effortlessly dyads transmit and detect signals, and how social status influences the process of transmitting and detecting social information. Gregory Jr. and Webster (1996) examined 25 Larry King interviews and stripped the audio recordings of their semantic content, leaving only non-semantic features left. They then examined the extent to which the dyadic recordings converged on similar acoustic features (e.g., vocal pitch, pace, intensity), finding a large effect for voice synchrony between King and the interviewees. The voices *converged* on the stable characteristics extracted from each speaker. Critically, though, was how convergence was achieved. When King was interviewing relatively lower status or less well-known interviewees, the interviewees modulated their voice to match King's. However, when King interviewed higher status, respected individuals (sitting president, head of state, royalty) King modulated his voice to match theirs. Thus, status moderated the direction of voice synchrony such that lower status individuals were more influenced by their higher status partners than the reverse.

Behavior and facial expressions are ecologically valid, but specific (e.g., face touching, playing with hair), can be rare events, and are not necessarily veridical read-outs of emotional states (Barrett et al., 2019). Neuroscientific approaches, like neural imaging (fMRI), offer temporal precision but present a challenge when attempting to study natural face-to-face interactions in which affect is typically experienced. We suggest that on-line peripheral physiological measures that are responsive to affective states and can be measured unobtrusively from two interacting partners can overcome many other measurement limitations. For example, on the temporal precision, the sympathetic nervous system generally responds within 3–5 s upon exposure to an affective stimulus (Blascovich, Mendes, Vanman, & Dickerson, 2011). Moreover, peripheral physiology can be obtained with little imposition on respondents allowing for people to interact in natural, unencumbered way (Mendes, 2009, 2013). Previous work provides suggestive data that individuals experience physiologic synchrony during social interactions, and that synchrony can occur across multiple physiologic indicators within the autonomic nervous system (e.g., Levenson & Ruef, 1992).

1.2.1 Physiologic synchrony

As noted, measuring behavioral synchrony can be challenging given that the behavioral signal might be too common or too rare, and there are few temporal laws that govern behavior. For example, how long after face touching occurs should a partner touch their face to conclude that mimicking has occurred? Using peripheral physiologic responses overcomes these limitations by providing continuous and on-line responses during face-to-face encounters with known temporal response profiles from an experience/mental state to a change in physiologic response. Peripheral physiological responses offer a response channel that reacts quickly to affective changes and allows for temporal precision to examine subtle changes over time between dyad members (Mendes & Muscatell, 2018). Here, we focus on peripheral physiological synchrony as one proximal measure of affect contagion.

1.2.2 History of physiologic synchrony

For almost a century, psychology has leveraged physiologic approaches to capture psychological experiences of individuals—including emotions, motivations, and attention (e.g., Cohen & Patterson, 1937; Darrow, 1929; Jacobson, 1930; Mittelmann & Wolff, 1939). In the 1950s, this individual-based approach was expanded to include pairs of people, as interest in understanding the interdependence between people's physiologic states grew. Much of this early work focused on therapy sessions, given the role that attunement to a patient's emotional states plays in the patient-therapist relationship. For example, similarity between patients' and therapists' heart rates map onto behavioral processes such as rapport (Coleman, Greenblatt, & Solomon, 1956; DiMascio, Boyd, & Greenblatt, 1957), suggesting that physiologic synchrony can facilitate positive social interactions. Following this early work, social scientists have used physiologic synchrony to study a host of close relationships, including romantic couples and parent-child dyads, and newly-acquainted dyads and teams; synchrony has been linked to relationship quality, individual differences like attachment, and the development of self-regulation and trust (Hill-Soderlund et al., 2008; Levenson & Gottman, 1983; Mitkidis, McGraw, Roepstorff, & Wallot, 2015; Suveg, Shaffer, & Davis, 2016; for reviews, see Timmons, Margolin, & Saxbe, 2015; Palumbo et al., 2016).

Arguably, the most well-known research examining physiologic synchrony in dyads is Levenson and Gottman's research with married couples. In this work, married couples engaged in conflict conversations while a variety of peripheral physiologic measures were obtained. Using analytic techniques developed specifically to analyze these data (bivariate time-series), they showed that physiologic synchrony was related to marital satisfaction and dissolution (Levenson & Gottman, 1983). In more recent work, couples who showed more "in-phase linkage" during shared positive emotion (similar rises and falls in peripheral physiology) had higher quality interactions, and reported higher relationship quality (Chen et al., 2021).

1.2.3 Physiological responses to measure affect contagion

To measure affect contagion using physiologic responses, a number of factors are important to consider. First, it is important to use measures that allow for (reasonably) natural face-to-face interactions that can increase ecological validity. Thus, while imaging techniques (fMRI) allow for powerful spatial identification of neural regions, the requirement of being supine in a magnet can interfere with natural dyadic exchanges. Similarly, EEG/ERP with its powerful temporal precision, poses limitations given its requirements to have precise time-locked responses to estimate event related potentials (Picton et al., 2000). Neuroendocrine responses, like cortisol and testosterone, are not well suited for multiple assessments over a typical conversation interaction given the "dump and release" of hormones, which prevent fine-grained data needed to identify time-varying rises and falls of affective states (Dickerson & Kemeny, 2004). Consider the temporal factors related to identifying cortisol in saliva, for example. The time from an affective state (like acute stress) to activation of the hypothalamic pituitary adrenal cortical axis (HPA) and in turn, to changes in salivary free cortisol would be on average of 10 to 15 min. The affective experience would also have to be sustained and intense enough to trigger the HPA, which typical social interactions would not be (see Dickerson & Kemeny, 2004, for a meta-analysis addressing these issues).

The autonomic nervous system might be an especially useful system to measure affective states as they unfold in social interactions. The ANS comprises two major branches: sympathetic and parasympathetic nervous systems (SNS and PNS), both of which are commonly examined in studies on emotion and physiology (Berntson, Cacioppo, & Quigley, 1993). The SNS functions, in part, to mobilize oxygenated blood from the heart to peripheral sites such as arms, hands, legs, feet, and the brain. The greatest change in SNS responding occurs with physical exertion, like sprinting or intense aerobic exercise. However, this system also activates in *non-metabolically (or minimally) demanding* situations; ones that do not by necessity require an increase in oxygenated blood (Mendes & Park, 2014). Measures that tap aspects of SNS that are commonly used in emotion and stress research include heart rate/interbeat interval, skin conductance, finger pulse transit time, peripheral skin temperature, pre-ejection period, stroke volume/cardiac output, pupil diameter, and local/global blood flow measures (pulse amplitude, peripheral resistance; Blascovich et al., 2011; Mendes, 2016).

The PNS is typically assessed with heart rate variability (HRV) measures that capture cardiac vagal influences on the heart. Initially, HRV—the time interval between each heartbeat—was believed to be a measurement artifact or nuisance, but further exploration into spontaneous changes in the timing of the heart cycle proved to be psychologically and physiologically meaningful. Though there are still disagreements on the specifics related to measurement, quantification, and psychological meaningfulness of HRV, these measures are often used by psychophysiologists given their putative sensitivity to valence and links to social engagement processes (Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008; Porges, 2007).

ANS responses can be obtained unobtrusively, continuously, and on-line allowing for social interactions to naturally unfold. In addition, most peripheral physiological responses, as noted above, have predictable and reliable temporal trajectories such that changes resulting from an affective state can be detected within a short-time frame (e.g., 3–5 s for sympathetic nervous system changes). These criteria point to two potentially useful autonomic nervous system indicators to use for physiologic synchrony: pre-ejection period (PEP) and heart rate variability (HRV).

Pre-ejection period (PEP) is a chronotropic (time-based) measure estimated as the difference from the left ventricle contracting to the aortic valve opening; it represents a pure measure of sympathetic nervous system activation given it is calculated during the heart cycle when there are only sympathetic influences (during systole; Brownley, Hurwitz, & Schneiderman, 2000). Psychologically PEP is related to activated, intense experiences, so it is best conceived as a general measure of arousal, rather than a valenced or emotion specific measure (cf. Bliss-Moreau, Machado, & Amaral, 2013). For example, in the circumplex model of emotions, PEP tracks with arousal/activation rather than valence (Barrett & Russell, 1999; Mendes, 2016).

Heart rate variability, specifically respiratory sinus arrhythmia (RSA), measures the activity of the cardiac vagus nerve and is considered a relatively pure measure of parasympathetic nervous system activation. The vagus nerve (cranial nerve X) originates in the medulla and innervates a number of organs including the heart. Porges' polyvagal theory (2007) argues that primates uniquely have vagal nerve modulation (cf. Grossman & Taylor, 2007), which has evolved as part of the social engagement system. One of the primary postulates of polyvagal theory is that social factors (affiliation, social engagement) or personality factors (optimism, bonding, compassion) can modulate vagal activity. Specifically, Porges contends that higher RSA (high cardiac vagal tone) can be used as an index of adaptive emotional regulation and responsiveness to the social environment. Cardiac vagal reactivity (specifically decreases from rest to an active task) have been related to a variety of affective and cognitive states like social engagement, attentional control, vigilance, and effort (Kassam, Koslov, & Mendes, 2008; Muhtadie, Koslov, Akinola, & Mendes, 2015; Porges, 2007).

PEP is sensitive to arousal states, but it is not high in affective specificity (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000; Mendes, 2016; Siegel et al., 2018). There may be an advantage to using PEP for affect contagion because other physiological indicators can be used simultaneously that might offer more specificity in terms of the psychological states they infer. For example, if one wanted to study how feelings of disgust might be shared, one could measure PEP and EGG (electrogastrography), which are uncorrelated physiologic responses stemming from different systems: sympathetic nervous and enteric systems. Gastric changes decrease during experiences of physical disgust (Shenhav & Mendes, 2014) and PEP could be used as the indication of intensity of responses and how this affective state is shared between two or more people. Similarly, PEP and RSA are relatively orthogonal (Berntson, Cacioppo, & Quigley, 1991), and these responses also tend to be uncorrelated (or minimally correlated) with neuroendocrine reactivity, like cortisol and adrenal steroids, and slightly to moderately correlated with other cardiovascular measures like blood pressure, cardiac output, total peripheral resistance, and skin conductance (Blascovich et al., 2011).

We argue that PEP, in general, is a useful ANS measure to measure affect contagion because of these unique properties. This would be especially the case during social interactions that are "arousing" or "activating," but could be either unpleasant or pleasant. Relatedly, RSA might be a useful measure during social interactions given its link to social engagement, but situations that are lower in arousal would be primary targets. While the SNS and PNS are relatively independent, in moderate to high arousing situations the systems operate reciprocally, such that high arousal situations result in strong SNS activation and typically a withdrawal of the cardiac vagal brake resulting in little to no influence of PNS (Weissman & Mendes, 2021).

In relying on peripheral physiological responses as the continuous measure of affect contagion between dyads and groups, it is important to note other possible channels of data that could be captured, and what the expected coherence between those channels might be. As we described earlier, ANS responses have the advantage of being continuous and on-line, so conversations and interactions would not have to be disrupted to obtain self-reported responses, even though self-reported responses in the moment might provide valuable insight into affect contagion processes. Some researchers have circumvented this limitation by measuring peripheral physiology in real time during a social interaction, and then having participants watch playbacks of the videos and use a sliding scale to conscious report how they were feeling at that time (Brown, West, Sanchez, & Mendes, 2020). Other approaches have examined emotional behaviors using trained observers who consider second by second information and code for verbal content, voice tone, context, facial expression, gestures, body movements, and emotional behaviors (e.g., specific affect coding system) to capture emotional variation as it unfolds (Chen et al., 2021).

These additional approaches can enrich the understanding of affect contagion but it is critical to understand that methodological channels of emotion, stress, and general affect often do not have high concordance (Blascovich, Mendes, & Seery, 2002; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Thus, it would be expected that physiological synchrony might yield different results that behavioral synchrony focused on emotional behaviors. Given this constraint, we argue that affect contagion using physiologic measures provides insight into the less consciously controlled features of shared emotions, whereas other channels, like expressions, voice, and behavior are capturing processes under more deliberate and effortful control.

1.2.4 Types of physiological synchrony

There are several analytic approaches when examining physiologic synchrony with different conceptual meaning and with various strengths and limitations. In this chapter, we review two common types of physiological synchrony that we have examined in the context of affect contagion, and we describe how they differ conceptually and analytically (cf. Butler, 2011). The first type is *physiological covariation,* which determines the amount of correlation between two (or more) individuals' physiologic responses extracted from the same time period (see top portion of Fig. 1). Conceptually, *physiological covariation results from shared experiences and environments*. To the extent that individuals are together and have a similar affective experience, the expectation is that *covariation* will be quicker (occur faster), greater (show larger magnitude of agreement) and positive (the slopes are in the same direction of change). Here, we will use the label *Partner A* ≈ *Partner B* to indicate physiological covariation.

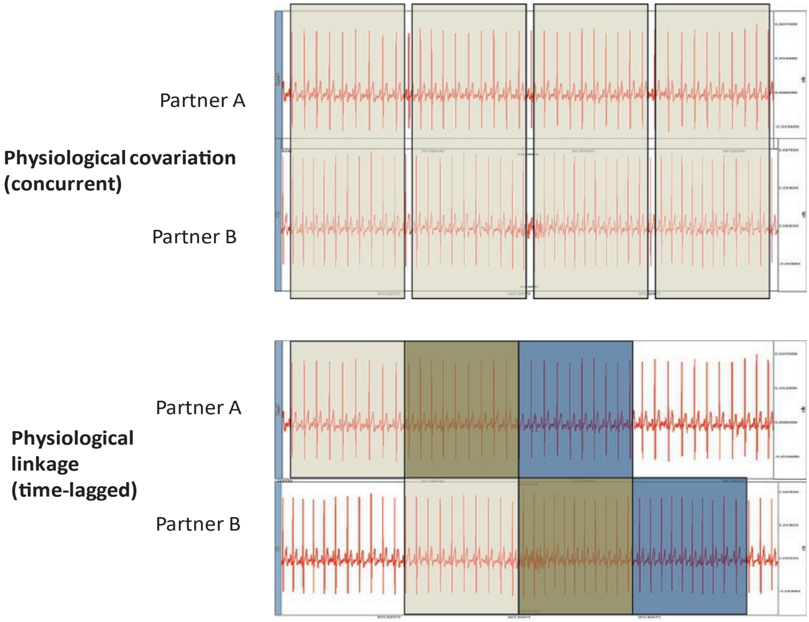

Fig. 1 Types of physiological synchrony: Upper panel shows physiological covariation and lower panel shows physiological linkage.

The second type of synchrony is called *physiological linkage* and focuses on how one individual's physiologic responses influence another person in a time-lag design (see bottom portion of Fig. 1). This approach uses one person's responses (e.g., Partner A) at time X to predict their partner's (Partner B) responses at time X + 1, *controlling for Partner Bs time X responses*. Conceptually, *linkage* is perceived to be an indication of the underlying social and affective processes by which one person *influences* another. Here we use the label *Partner A → Partner B* to indicate that Partner As responses are used to predict Partner Bs responses. In other words, partner A would be (in part) the catalytic agent for change in partner Bs responses. This analysis would be followed by testing the directional influence where the model would then test Partner B → Partner A. In this chapter, we describe studies with both types of physiologic synchrony, and even though the synchrony types are different conceptually and analytically they both represent a type of affect-contagion: covariation taps the similarity in perception of situational factors, whereas linkage captures more direct affective influence from one partner to another.

Though typically the process of linkage focuses on *positive* slopes—one person's increase in sympathetic nervous system (SNS) responses predicts their partner's subsequent increase–one can also interpret *negative* slopes—one's person's increase predicts their partner's subsequent decrease. In general, negative slopes might be more likely to occur in conflictive or competitive contexts, whereas positive slopes are more likely to occur in cooperative contexts (Kraus & Mendes, 2014; West, Koslov, Page-Gould, Major, & Mendes, 2017). These complementary effects may prove to be especially important when examining dyads that differ in race or other social category membership. In general, a targets' affect evokes matched affect in their partners (target's anger expression evokes perceiver's anger expression), however Weisbuch and Ambady (2008) found that outgroup members can evoke *complementary* emotional responses (target's anger expression evokes perceiver's fear expression). Physiologic synchrony allows for the direct interpretation of matched versus complementary dyadic responses.

2. Theory of affect contagion

In Fig. 2, we present a theoretical model of affect contagion that considers the predictors, moderators, outcomes, and underlying psychological

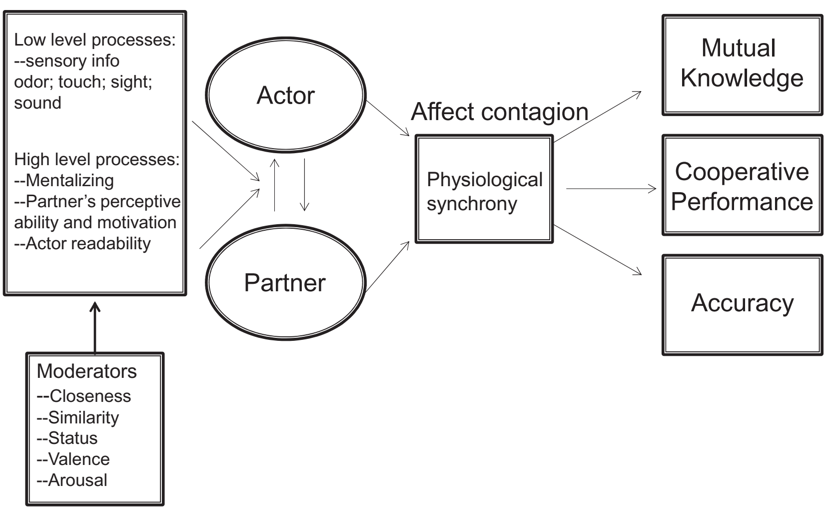

Fig. 2 Model of affect contagion between dyads.

processes of affect contagion. For ease of clarity, we refer to the *actor* as the person whose emotional state is being transmitted, and the *partner* as the person detecting and "catching" the affective state.

2.1 Antecedents of affect contagion

We first examine that processes underlie how partners become attuned to one another's affective states during interactions. We have separated categories of processes into two broad categories: *low-level processes* and *high-level processes*. Low-level processes are primarily sensorial information that is effortlessly detected and visceral, and include information gathered from odor, touch, vision, and sound. For example, mob mentality assumes that strong, high arousal affect triggered by dramatic events do not necessitate complex higher order cognitions of person perception but rather instinctual, reflective responses (e.g., Granovetter, 1978; Watts, 2002). Pre-verbal infants respond to their mothers' stress reactions within minutes of being reunited even though the mother experienced the stressor when separated from the baby (Waters, West, & Mendes, 2014), indicating that infants engage in low level processes as a way to socially attune with their caregivers. Low level processes likely are engaged in situations when the threat or intensity of the signal is large and unmistakable (i.e., apparent in face, body, behavior, or voice).

High-level processes are related to the ability of partners to read the actor's emotions (Epley & Waytz, 2010). They are dyadic in nature and include the motivation to attend to the actor's behaviors (Kunda & Thagard, 1996), the ability to map these behaviors onto the actor's emotional state (i.e., being a "good perceiver"; Funder, 1995), and, from the perspective of the actor, providing clear, behavioral indicators of one's emotional state (i.e., being a "good target", Funder, 1995). These processes also include *mentalizing* or the active approach of trying to imagine what your partner is thinking or feeling (Frith & Frith, 2006). Similar to the idea of *motivated empathy* (Cameron, Scheffer, Hadjiandreou, & Anderson, 2022), mentalizing or empathizing are distinct from a natural emergence of a felt state based on other's suffering; they are strategic and effortful processes used to feel and/or understand another person. Processes in this high-level route are presumed to be more effortful, require theory of mind, and are likely to take relatively longer than low-level processes.

2.2 Context and moderators of affect contagion

In our model, we identify moderators that influence antecedents of affect contagion. These include, but are not limited to, closeness, similarity, status, valence, and arousal. In some cases, we have examined these moderators directly—examined affect contagion of dyads who differed in similarity of group identity—and on other occasions have used the moderator as the context to study affect contagion—examining affect contagion within dyads who have a preexisting close relationship like a mother and infant.

Closeness of the dyad (or group) has been the most commonly studied context of affect contagion with a fairly extensive literature on romantic couples, family units—especially parents and children—and less studied are friends, roommates, and work groups. The corpus of the argument that closeness is a powerful factor in affect contagion is probably obvious; dyads who have more shared experiences and interdependence would be more likely to have similar responses to the same environment (shared reality) and engage in more mentalizing about each other's affective states. It is important to note, though, with infant and young children, prior to the development of theory of mind, we do not anticipate higher level processes with parent and child interactions, and typically focus on low level processes and covariation models.

Similarity is broadly defined in our model to include group identities along racial or ethnic identities, age, gender or sex identity, sexual orientation, political ideology, and socio-economic status to name a few. We suggest that dyadic similarity influences both low level and high level processes. Mutual knowledge and shared reality are processes that are enhanced with similarity (Hardin & Higgins, 1996). As people draw from similar experiences their reaction to environments will be more similar. For example, two Democrats who hold a disdain for Trump might both be disgruntled at the sight of a red baseball cap, and that small signal might have similar influences on their affect. Their similar affective reactions could be captured by a covariation model. However, if one person has a strong reaction that is then detected by their partner, then the then there might be a linkage effect.

Status is a likely moderator of affect contagion for both higher and lower status individuals. Decades of social psychological research has shown that individuals of lower social standing are more likely to be vigilant of their social environment and wait for cues from higher status others (Frable, Blackstone, & Scherbaum, 1990). Moreover, higher status individuals are more likely to exude dominance signals and show more autonomy and independence than lower status ones. These factors make it highly likely that higher status individuals will be more likely to set the affective tone of an interaction and be more influential in influencing lower status partners (see also Gregory Jr. & Webster, 1996).

We argue that valence is an important moderator of affect contagion. Specifically, we contend that negative emotions, stress, and avoidance motivation, for example, will be more likely to be transmitted and caught in social interactions. There are several reasons for this theorizing. The first is the negativity bias, in which there is a "greater weight given to negative entities…" (Rozin & Royzman, 2001). Rozin and Royzman (2001) speculated that the negativity bias would be observed in many factors inherent in social interactions such as impression formation, empathy, and emotions. Additionally, negative states like stress, anger, and antipathy have a strong physiologic response relative to positive emotions, which tend to have smaller and even counter-regulatory influences (i.e., reducing physiologic reactivity; Siegel et al., 2018; Fredrickson, Mancuso, Branigan, & Tugade, 2000). Thus, the signal for negative states can be stronger and easier to detect than the one for positive states. Finally, from an evolutionary perspective, the importance of detecting negative or threat signals from conspecifics would be greater than detecting safety signals (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001) though the detection of negative or threat signals over positive or safety signals might be due to greater diversity in the former and similarity in the latter (Unkelbach, Alves, & Koch, 2020).

Finally, arousal, the state of being activated, from an affect contagion perspective might be the one moderator that is essential to physiologic synchrony. To detect fluctuations and changes in physiology from one psychological state to the next requires some change in activation. Similar to emotion and stress research, bodily changes are perceived as sine qua non of affective states. This means that while it might be possible to have affect contagion of low-arousal states like calm and contentment, one would likely have to examine a physiologic system sensitive to capturing changes in low arousal states, specifically the PNS. As we will describe below, the majority of our research has focused on physiologic synchrony of the SNS and used moderate to high arousal tasks and contexts to examine these processes. There have been very few situations where we examined synchrony in the PNS and they were exclusively for situations in which we targeted low-arousal and/or positive affective states.

2.3 Consequences of affect contagion

The right side of our model includes possible consequences of affect contagion. To date, we have focused more on the left side of the model—antecedents and moderators—than the consequences of affect contagion. Here, we briefly theorize on possible consequences of affect contagion.

Our first word of caution is that we do not think that affect contagion will necessarily result in unambiguous positive outcomes. Attending to another person's behaviors and having synchronized physiology can lead to increased understanding, accuracy, and mutual knowledge, which is not the same as liking and affiliation. Mutual knowledge thus would allow for individuals to better predict their partner's behavior, such as whether that partner is friend or foe. We do suggest, though, that one possible beneficial consequence is better cooperative performance. Increasing the precision of prediction of a partner can increase one's ability to cooperate effectively (Van Bavel, Pärnamets, Reinero, & Packer, 2022).

Interpersonal accuracy (i.e., understanding one's partner's thoughts, feelings, and intentions) is associated with positive relational outcomes, such as satisfaction and longevity in romantic relationships (Fletcher & Kerr, 2010), cross-race friendship development (Shelton & Richeson, 2005), coordinated behaviors among task-focused groups (Stahl, Maznevski, Voigt, & Jonsen, 2010), and positive health outcomes of minorities following racially-discordant doctor-patient interactions (Ashton et al., 2003). Given the conceptual overlap between coordinated behaviors and physiological linkage and coordinated behaviors and interpersonal accuracy, accuracy may be related to synchrony such that dyads that have stronger and more positive physiologic synchrony will also be more accurate in their judgments of each other (see Brown, West, Sanchez, & Mendes, 2021 as one example). We note that this last consequence, accuracy, might initially sound tautological—better partner perception is an antecedent to affect contagion, and a consequence of synchrony—but our point is that a positive feedback loop can increase the bi-directional associations between accuracy and affect contagion. Accuracy can trigger stronger synchrony, and that increased synchrony can improve interpersonal accuracy. A strong test of this would be time-varying effects such that the greater the increase in synchrony during the interaction would increase interpersonal accuracy over time.

2.4 Analytic approaches for physiologic synchrony

We have developed several analytic approaches to examine the process of affect contagion, which vary depending on the approach (covariation or linkage), whether we are examining affect contagion in groups or dyads, and what the design of the study is (e.g., are the dyads doing the same task the entire study, or do they switch tasks, and we have different expectations about affect contagion when tasks are dependent versus independent). We assume that physiologic data are collected repeatedly over time, and there are sufficient data to capitalize on the repeated measures nature of the data. For example, our studies range in time from 20 min to an hour (in some cases, longer), and physiologic data are scored in 1-min bins or smaller (20 or 30 s). We also assume that all members of the dyad have physiologic data for the same time points, at least during the interactions. For example, in a study in which one participant undergoes a Trier Social Stress Test and the other person watches a control video, we will have physiologic responses that are independent for the dyad (or group) members, which would not be analyzed using a dyadic approach (i.e., the non-independence between members would not need to be accounted for). However, once the two individuals are united, then data become dyadic at this point in the study.

Although our approaches differ in how we estimate the effects of synchrony, they all utilize a multi-method approach to examining affect contagion, in which individuals are nested within dyads (or dyads within teams), and crossed with time (i.e., a two-level crossed model; see Thorson et al., 2018). In Thorson et al. (2018) we provide a detailed description of how data need to be structured and the syntax for these models. We also provide a detail of the power analysis approach we use (using Monte Carlo simulations). Below are brief descriptions of the analytic approaches to each.

2.4.1 Physiologic covariation

Physiologic covariation requires that two dyad members have physiologic data at the same time points, and the goal is to examine the within-time-point covariation. One approach is a nomothetic one, in which covariation is estimated as a fixed effect in a multiple level model, treating one person's physiologic score at one time point as a predictor of the partner's score at that same time point (a partner effect in dyadic design). For example, in West, Pearson, and Stern (2014) in which we examined the covariation between mothers' SNS response (PEP reactivity) and infants' response (HR reactivity), the mother's score was treated as the criterion (dependent variable) and the infant's score as the predictor variable (this is one of the few occasions when we used different physiologic responses within a dyad for the simple reason that infants would not tolerate the equipment to obtain PEP). We note that this analysis does not imply causation, but rather captures the relationship between the two variables. We applied a linear growth curve model approach to examining affect contagion by further moderating the effect of infant HR on mother PEP by linear time, which allowed us to assess whether covariation increased or decreased over time. Lastly, at the level of the random effects, we estimated the mother's intercept, slope, and intercept-slope covariance (a saturated random effects model). This model is flexible in that additional moderators can be included (in this case, mother's stress condition) to test for which conditions affect contagion is the strongest. We refer the reader to https://tessawestlab.hosting.nyu.edu/lab-resources.html (under data sets) for a generic example annotated syntax, and https://mendes.socialpsychology.org/files for the data and specific syntax for Waters et al. (2014).

We note that in this approach, the researcher will need to make a choice of whose data is treated as the DV and whose data are the IV. This choice is not arbitrary—only one partner's data can have random effects estimated (the DV). We chose the mother's data in this case given that mothers underwent the stress (or control) manipulation coming into the interaction, and our question was explicitly regarding the extent to which the baby detected changes in the mother's affective response.

2.4.2 Physiologic linkage

We provide an in-depth description of the analysis approach to physiologic linkage in Thorson et al. (2018). In this approach, the data are structured as a person period pairwise file, which means that every person has a line of data for each time point, and their partner's data are a separate variable on the same line. For example, Person A's PEP score at minute 1 would be one line, and their partner's score "Partner PEP" would be a separate variable with a score at minute 1 on that same line, with everyone being both an "actor"—their own data—and a "partner." In our work, we apply a *stability and influence* model approach whereby the participants' PEP reactivity at one point is treated as a function of their own reactivity at the prior time point (30 s prior in most cases, the stability path) and their partner's reactivity at that prior time point (the linkage path). Because the nonindependence of observations is taken into account, the degrees of freedom in these analyses vary across different tests.

To test whether linkage is moderated by study factors (e.g., "stress condition" of one partner), we would moderate the linkage and stability paths by these variables. Following the recommendations of Ledermann and colleagues (Ledermann, Macho, & Kenny, 2011), the initial model is always fully saturated at the level of the fixed effects, meaning that all moderators can influence the stability and linkage paths. We also estimate the random effects of both partner's intercepts, their stability paths, and their linkage paths (for a full discussion of the random effects, see Thorson et al., 2018). We refer the reader to Tables 3 through 7 in Thorson et al. (2018) for theoretical equations, example data sets, and annotated syntax for the stability and influence approach to physiologic linkage.

3. Empirical studies of affect contagion

Over the past several years, we conducted dyadic and small group studies examining the conditions under which affect contagion occurs, using physiologic synchrony to measure it (see Table 1 for an overview of past studies). One of our first series of studies we published focused on close-other dyads (parents and children), where we experimentally manipulated factors thought to modulate affect contagion—specifically high arousal negative emotion (Waters et al., 2014; Waters et al., 2017; Waters et al., 2020). In our next set of studies, we focused on newly-acquainted dyads, with an emphasis on how similar dyads were to each other in terms of their social identities; whether they had a similar socioeconomic background, racial group membership, or gender (del Rosario et al., 2022; Kraus & Mendes, 2014; Tan et al., 2022; West et al., 2017). We focused on whether the processes that influence affect contagion—nonverbal behavioral displays from actors and motivations from perceivers, for example—differentially influence affect contagion for similar and dissimilar pairs. In addition to this work, we also focused specifically on the role of social status (experimentally manipulated using random assignment and quasi-experimentally manipulated using real indicators of socio-economic class) in shaping how people behave in interactions, and what behaviors capture the attention of their partners. Although many of our studies have focused on affect contagion of high arousal negative emotions—stress and anxiety in particular—others have focused on low arousal negative affect, such as sadness, and low arousal positive affect, such as relaxation, to test the boundary conditions of affect contagion in close-other and new acquaintance interactions (e.g., del Rosario et al., 2022; Waters et al., 2017). By testing various levels of arousal in our studies, we are able to examine which branches of the autonomic nervous system are most sensitive to capturing the process of affect contagion. Lastly, we have examined real group settings such as group therapy and operating room settings to study how natural groups influence and are influenced by each other.

Table 1 Overview of affect contagion studies.

Study	Relationship	Type of synchrony	Design/IV/manipulation	Physio measure	Putative process: High, low	Primary observation
Waters et al. (2014)	Close other dyads: infant-mother	Covariation	3 levels: Mother's received negative, positive, or no feedback during an acute evaluative stressor	PEP for mothers; HR/IBI for infants	(not examined) Assumed low level processes, including mother's voice, touch, and face/body	Stronger physiological covariation in the negative feedback condition than the other conditions
Waters, West, Karnilowicz, and Mendes (2017)	Close other dyads: Infant-mother	Covariation	2 × 2 Mother's stress (negative feedback or calm) × Mother's touch (infant on lap or in high chair)	PEP for mothers; HR/IBI for infants; RSA	Low level process, touch	PEP-IBI covariation increased over time in the touch + stress condition, and decreased in the no-touch + stress condition RSA covariation strong and positive in the relaxation condition, none in the stress condition.
Waters, Karnilowicz, West, and Mendes (2020)	Close other dyads: Child-mother and child-father	Linkage	2 (Parents Emotional suppression × no instructions) following an acute stress	PEP	High level processes, mentalizing	Stronger linkage from mothers to children in the suppression condition than the control condition. Stronger linkage from children to fathers in the suppression condition than the control condition.
West et al., 2017	New-acquaint-ance dyads	Linkage	2 (same-race or cross race dyads), White-White or Black-White dyads	PEP	High level Processes: Motivation to attend to a partner's anxious cues	In cross-race dyads, AAs showed stronger linkage to EA partners the more anxious those EA partners were. Linkage was positive for same-race dyads, regardless of partner anxiety.

Tan, West, and Mendes (2022)	New-acquaint-ance dyads	Linkage	2 (same SES or mixed SES dyads) same SES either low-low or high-high; mixed low-high SES	PEP	High level processes: motivation to attend to a partner's mental states	Low SES participants showed stronger linkage to their partners than high SES participants, regardless of the status of their partner.
Kraus & Mendes, 2014	New-acquaint-ance dyads	Linkage	3 (sartorial cues: high status, low status, or no change) Used a sartorial manipulation of one dyad member	PEP	High level: Motivated attention to cues associated with high status	Partners of high status men showed stronger linkage to their partners than partners of low status/control men.
del Rosario, West, Gogalniceau, and Mendes (2022)	Surgery teams	Covariation	2 (Risk of the surgery: high vs low) x 3 (Status of the surgery team member: Senior surgeon, junior surgeon, surgical nurse)	IBI	Low level: voice High level: Motivation to attend to other surgery team members for cues of stress	In high-risk surgeries, junior surgeons and surgical nurses had negative covariation with senior surgeons. In low-risk surgeries, senior surgeons and surgical nurses showed positive covariation
Thorson, Dumitru, Mendes, and West (2021a)	New-acquaintance small groups	Linkage	Status of group members: (high, moderate, low status). Two group members (the high and low status) were assigned to persuade the group; the other group members (medium status) were not.	IBI	High level: Motivation to attend to cues associated with status; motivation to persuade group members	Regardless of status, successful persuaders had group members who showed physiological linkage to them

Continued

Table 1 Overview of affect contagion studies.—cont'd

Study	Relationship	Type of synchrony	Design/IV/manipulation	Physio measure	Putative process: High, low	Primary observation
Thorson, Dumitru, and West (2021b)	New-acquaint-ance small groups	Linkage	2 (high, low status) high status assigned to persuade her group	IBI	High level: Motivation to attend to cues associated with status	High status women who were successful at persuading their groups showed stronger linkage to their group members than unsuccessful high-status women
Thorson et al., 2021c	Pre-existing small therapy groups of methamphetamine users	Linkage	2 (nasal spray: Oxytocin, placebo); repeated sessions	IBI	Low level; increased expressivity and perception due to OT High level: motivation to attend to thoughts and feelings of other group members,	Stronger linkage immediately between group members in the oxytocin condition than the placebo condition
Brown et al. (2020)	New-acquaint-ance dyads	Linkage	Measured emotional empathy. One participant completed a series of extreme emotion inductions, re-lived this with a partner "the listener"	PEP	High level: Empathy-based motivation to share a partner's emotions	Empathy was not directly related to physiological linkage. Listeners higher on empathy who showed stronger linkage to experiencers were more accurate in their emotion perception
del Rosario et al., 2022	New-acquaint-ance dyads	Linkage	2 (emotion induction of actor: sad, control) × Dyad Gender (men, women)	PEP	High level: Motivation to attend to a partner; ability to capture the attention of a partner	Male dyads with sad actors showed physiological linkage. Female dyads did not link more as a function of actors' emotions.

3.1 Affect contagion in parent-child relationships

We begin with an overview of the first set of studies to capture dyadic physiologic synchrony in the lab. In our first published study (Waters et al., 2014), we tested the idea that stress, when experienced by a mother (not while in the presence of the child) could be "caught" by their infant once the two were reunited. Several studies have found evidence for naturally occurring physiologic synchrony between mothers and children (for cortisol in particular, see Hibel, Granger, Blair, & Cox, 2009; Papp, Pendry, & Adam, 2009; Williams et al., 2013), but little work had examined the process experimentally, with the emotional experience of a mother being manipulated prior to the interaction. Negative affect is typically more salient and impactful than positive affect for both adults (Baumeister et al., 2001) and infants (Sorce, Emde, Campos, & Klinnert, 1985). We reasoned that infants would experience stronger affect contagion, manifested as stronger physiological covariation, when their mothers experienced a strongly-valenced negative emotion manipulation, compared to a positive experience or neutral-affective one.

To test the outcome of physiologic covariation, we examined infants' behaviors after they were reunited with their mothers. Nearing the end of their first year, infant behavior begins to reflect their mother's emotional cues (Walden & Ogan, 1988), and when mothers exhibit negative emotions, infants interact with their environments with greater weariness (de Rosnay, Cooper, Tsigaras, & Murray, 2006). Thus, we reasoned that behavioral indicators of avoidance, when accompanied by physiological covariation, would point to possible consequences of affect contagion.

To test these ideas, we first separated mothers and their twelve-to-fourteen month old infants, and randomly assigned mothers to experience either (1) stressful positive-evaluation task, (2) stressful negative-evaluation task, or (3) non-stressful control task. In both the positive and negative evaluation conditions, mothers gave a 5-min speech about their strengths and weaknesses to a panel of two evaluators (modified Trier Social Stress Test; Kirschbaum & Hellhammer, 1994), followed by a 5-min question and answer (Q&A) session. In the positive-evaluation condition, the evaluators became progressively more positive during the interaction by smiling, nodding, and leaning forward while the participant spoke, whereas in the negative-evaluation condition, the evaluators became progressively more negative, frowning, shaking their heads, crossing their arms, and leaning back. By including a positive condition, we were able to examine whether affect contagion was stronger in the heightened arousal conditions, regardless of valence (positive or negative). In the control condition, mothers were instructed to deliver the speech and verbally responded to questions written on cards while alone in the room. Thus, the control condition was similar to the experimental conditions in terms of the metabolic demands (i.e., speaking aloud, answering the same questions) but did not have the social evaluative component.

After the speech task, the infant rejoined the mother for a reunion period in which the mother put the child on her lap. The mother and infant then were interviewed serially by two pleasant-acting female interviewers, who sat across from the mother–infant dyad, and engaged the mother in a short conversation about the infant's development, and then offered the infant a toy. At the completion of the study, we coded infant behavioral avoidance toward the experimenter (an unfamiliar other). Behavioral indicators ranged from passive (e.g., gaze aversion) to active (e.g., twisting bodily away) avoidance of the interviewers (Murray et al., 2008).

To capture physiologic linkage, we measured mothers' sympathetic nervous system (SNS) reactivity, specifically, pre-ejection period (PEP; the time from contraction of the left ventricle to opening of the aortic valve). As described above, PEP is a time-based measure that is calculated from the time of left ventricle contraction to the opening of the aortic valve and is considered a pure measure of SNS (no PNS influence). We measured infant reactivity using heart rate (beats per minute). Infants would not tolerate the impedance tape used in impedance cardiography, which completely encircles the neck and torso, so we only measured ECG on infants. To capture physiologic synchrony, we measured within-time point covariation between mother PEP and infant HR, which captures the strength of correlation between two individuals' physiology within a single time point. Conceptually, we were interested in the degree to which mothers and their infants experienced similar affective experiences during the interaction, and whether the strength of that similarity varied as a function of the mother's experimental condition.

Results indicated strong evidence of affect contagion, both for physiologic covariation and for infant behavior. Mother–infant dyads showed greater physiological covariation after mothers experienced a negative stressor than after they experienced a positive stressor or went through the control task, and the strength of covariation increased over time. Moreover, infants whose mothers were evaluated (either in the negative or positive evaluation condition) were more avoidant toward strangers than those in the control condition. These findings provided initial experimental evidence of affect contagion within infant-mother dyads, even when the emotion induction took place outside of the dyadic encounter. While this work showed evidence of affect contagion and for the indirect ways in which a mother's stress can affect her infant's physiology, the initial study did not provide insight into the process through which affect contagion occurred. What cues were mothers giving off that infants detected? How was affect contagion happening?

As proposed in Fig. 2, there are many routes through which physiologic synchrony can occur between interaction partners. We reasoned that infants would likely be influenced by their mothers via "low level" signals like changes in mothers' facial expressions, odor, posture, vocal tone, prosody, and/or touch. For infants who are "catching" their mothers' affective state, these processes were unlikely due to complicated higher-level thinking or motivation, but rather, attunement to bodily cues expressed by their mother. While many of the sensorial signals were possible, our follow-up study explicitly manipulated the role of touch in facilitating mother-infant physiologic covariation. Touch seemed like a likely candidate as a mechanism because it plays a critical role in infant emotion regulation (Feldman, Singer, & Zagoory, 2010; Field, 1998) and negative emotions can be conveyed via touch (Hertenstein, Holmes, McCullough, & Keltner, 2009), whereas warm, loving touch can reduce neurophysiological reactivity to stressors (Coan, Schaefer, & Davidson, 2006; Feldman et al., 2010; Grewen, Anderson, Girdler, & Light, 2003). Infants in our study sat on their mothers' lap during the post stress exchanges, and we theorized that mothers' touch might be a proximal cause for changes in infant physiological reactivity.

We tested the possibility that touch is a critical moderator of affect contagion in our follow-up study (Waters et al., 2017) by experimentally manipulating whether mothers touched their infants following the affect induction manipulation, or not. We also expanded our study of affect contagion beyond negative emotion, to include a positive, low arousal emotion induction condition. By doing so, we were able to test the possibility that synchrony can occur for both the sympathetic nervous system, which is associated with stress and threat, and the parasympathetic nervous system, which is associated with relaxation and calm responses.

In Waters et al. (2017), mothers and their 12-to-14-month-old infants came to the lab, and consistent with Waters et al. (2014), were initially separated from each other. Mothers and infants underwent a baseline period at the start of the study (after sensors were applied), and physiologic data were collected continuously throughout the study. After the separation, mothers then were assigned to one of two emotion induction manipulations: a high arousal stress task similar to the one used in Waters et al. (2014), whereby they discussed their strengths and weaknesses to a panel of two evaluators (one male, one female), followed by a 5-min Q&A session during which the evaluators gave negative nonverbal feedback (head-shaking, arm crossing, frowning), or a low arousal positive affect relaxation task whereby mothers watched a 5-min video of images of family members engaging in positive encounters, followed by a 5-min video of nature scenes accompanied by soothing music (Human, Thorson, & Mendes, 2016).

After the emotion induction, the infant rejoined the mother for a 5-min reunion, at which point the touch manipulation was introduced: Half of the mothers received their infants on their laps (touch condition), and the other half had their infants placed in a high chair facing them by an experimenter, and were told not to touch their infants because touch would (falsely) interfere with the signals (no-touch condition). Mothers and infants then played together with age-appropriate toys, followed by the mother being interviewed by a familiar experimenter for 1 min. The experimenter played with the infant for 3 min, after which they rated how withdrawn (versus approach) the infant was toward them, and how anxious and comfortable the infant appeared. These items were averaged for a measure of infant comfort.

We used impedance cardiography (ICG) and electrocardiography (ECG) on mothers to record SNS and PNS, which allowed us to calculate pre-ejection period (PEP; consistent with Waters et al., 2014) and respiratory sinus arrhythmia (RSA). RSA (high-frequency heart rate variability) represents the change in heart period and partly reflects the influence of the cardiac vagal nerve and provides a reasonable measure of PNS. For infants (who would not tolerate the mylar bands applied to the neck and torso, as in Waters et al., 2014), we only measured ECG, which provided measures of inter-beat interval (IBI) and RSA. Consistent with Waters et al. (2014), we examined physiologic covariation between mothers and infants by examining the within-time-point correlation between the mother's PEP and the infant's IBI (for SNS reactivity) and the mother's RSA and the infant's RSA (for PNS reactivity).

In Waters et al. (2017), we again found evidence for affect contagion, measured via physiologic covariation, for both SNS and PNS reactivity. When mothers were in the relaxation condition, covariation for RSA was positive, indicating that both mothers and infants had similar affective states. In the stress condition, RSA covariation was near zero. Interestingly, this effect held across touch and no-touch conditions. It is possible that we did not identify the critical variable that enables affect contagion of calm states and that low arousal affective states are transmitted through other processes, such as posture and tone of voice—a critical question for future research.

When mothers were in the stress condition, the pattern of effects for covariation of SNS responses were a little more complicated in that they varied over time, which we did not hypothesize. Recall that we hypothesized that touch would facilitate covariation of SNS responses, which are the most strongly activated for intense, high arousal emotions. We found that in the touch condition, covariation increased over the course of the study, suggesting that touch can facilitate affect contagion. In contrast, in the no-touch condition, covariation started off positive but decreased over time. These findings have important implications for how affect contagion can spread in everyday interactions between mothers and infants, given that touch is not only an integral part of the mother-child relationship, but practically speaking, is often unavoidable. Taken together with Waters et al. (2014), these findings provide further evidence that mothers' emotions–when induced outside of the interaction context–can spread to infants, and directly impact their behavior.

In our most recent examination of affect contagion in close-other dyads, we expanded the study of mother-infant dyads to study affect contagion in mother-child and father-child dyads, in which children were 7-to-11 years old. We borrowed the methodology of Waters et al. (2014) to study the spread of high arousal negative emotion—stress in particular—only here, we included an emotion suppression condition, to examine whether affect contagion between parent and child would increase when the parent was instructed to suppress their negative emotion. We focused on the effect of suppression (i.e., the deliberate attempt not to externally express or display an emotional experience; Gross, 1998) because of its well-established backfiring effect. Suppression not only leads to heightened physiological arousal in the suppressor, but also, in the suppressors' naïve social partners (relative to non-suppressors and their social partners; Ben-Naim, Hirschberger, Ein-Dor, & Mikulincer, 2013; Butler et al., 2003; Peters & Jamieson, 2016; Peters, Overall, & Jamieson, 2014). Yet suppression is a common strategy used by parents when interacting with their children (Le & Impett, 2016). Moreover, by randomly assigning some parents to suppress their emotional experience, we could test the causal impact of suppression on physiological synchrony. We theorized that there would be stronger physiologic synchrony in the suppression condition than in the control condition, and that suppression would not only affect physiologic responses, but behaviors as well.

Parents' habitual use of suppression has been linked to dismissive responses (Hughes & Gullone, 2010; Le & Impett, 2016; Low, Overall, Cross, & Henderson, 2019), reduced warmth and liking (in new acquittance dyads; Butler et al., 2003) and engagement in parent-child dyads (Shaffer & Obradović, 2017). Drawing from this work, we coded behaviors that were relevant to the different components of the task: a conflict conversation, a cooperation task, and free play. We examined whether parent suppression impacted the extent to which parents and children were warm, engaged, and critical toward each other.

A final goal of this research was to compare physiologic synchrony in mother-child to father-child dyads. Comparing mothers and fathers may be particularly salient in the context of parent emotion suppression because men are more likely than women to consistently use suppression as an emotion regulation strategy in day-to-day life (Tamres, Janicki, & Helgeson, 2002; Zimmermann & Iwanski, 2014). We theorized that if fathers suppress their emotions more than mothers do, children may be more readily influenced by their suppressing fathers' stress (i.e., stronger linkage and more compromised interactions) than their mothers' stress.

In the study, nearly equal numbers of mothers and fathers completed a laboratory stressor, a modified Trier Social Stress Test (TSST; Kirschbaum & Hellhammer, 1994, consistent with the prior studies in mother-child affect contagion). They were asked to give a 5-min speech about themselves and answer 5 min of questions in front of two evaluators (one male, one female). To increase feelings of social evaluation, during the TSST the evaluators provided negative nonverbal feedback to the parents, including head-shaking, arm crossing, and frowning. Parents were then randomly assigned to the suppression or control condition and told that they would be reunited with their child. In the suppression condition, parents were told that "in the following interactions with your child, try to behave in such a way that your child DOES NOT KNOW that you are feeling anything at all. Try NOT to show any emotion in your face or your voice. In other words, mask any emotion you may feel so that your child is NOT AWARE of them" (following Richards, Butler, & Gross, 2003). In the control condition, parents were instructed to act naturally with their child, as they would at home. Children were not in the room at the time of the

Trier or suppression manipulation. Parents and children were then brought to the same room, where they completed a 6-min conflict conversation in which they discussed of the greatest sources of conflict in their relationship. They then completed a 6-min cooperation task in which they had to work together to build a block structure according to a set of instructions (see Waters et al., 2020 for a detailed description), followed by a 6-min free play episode. Two trained raters, blind to experimental condition, coded the behaviors of parents and children for warmth, engagement, criticalness (during the conflict conversation).

Parent and child SNS responses were recorded continuously throughout the study, and we used pre-ejection period (PEP, as described above) to examine whether dyad members showed physiological linkage from one 30-s interval to the next, we estimated a stability and influence model (Thorson et al., 2018), in which participants' PEP reactivity at one point was treated as a function of their own PEP reactivity at the prior time point (i.e., the stability path) and their partner's PEP reactivity at the prior time point (i.e., the influence or linkage path). Thus, the stability path reflects how strongly a person's score at time t is predicted by their score at time t-1, and the influence path reflects how strongly a person's score at time t is reflected by their partner's score at time t-1. These paths reflect the average level of stability and influence across all the time points in the study. Influence, as described above, provides an indication of the underlying social and affective processes by which one person influences another (e.g., Gottman, 1994). Dyads in this study completed a variety of tasks which involved conflict and cooperation, and by estimating linkage, we were able to examine whether the effect of affect contagion varied not only as a function of these tasks, but also, whether children synchronize to parents, or vice versa. In other words, we utilized a method that allowed us to capture direction of causality between parent and child.

We found partial support for our hypothesis that stress contagion, measured via physiologic linkage, would be stronger for dyads with a parent in the suppress condition. Children whose mothers were in the suppression condition became positively linked to their mothers' physiology, particularly during the conflict conversation (with no evidence of linkage in the cooperation and free play tasks). However, we did not find the same pattern of effects for father-child dyads. In the suppression condition, physiologic linkage was found, but in the opposite direction of what we found for mother-child dyads: Children influenced their fathers' physiologic responses, not vice versa. Consistent with the mother-child dyads, no effects for linkage were found for the cooperative task or free play. One possible explanation for this finding is that fathers' more regular use of emotion suppression (compared with mothers) may result in children becoming habituated to and, thus, less influenced by fathers' suppression compared with mothers' suppression. Why, however, would fathers become linked to their children? One idea is that the conflict conversation—where we found evidence for physiologic linkage—was more novel or demanding for father than mothers, which made them more susceptible to being influenced by (i.e., linking to) their children's physiology, although this hypothesis would need to be formally tested.

Despite the different pattern of physiologic effects for father-child and mother-child pairs, patterns of behavior were consistent across both. Parents and children appeared less warm and less engaged, and marginally more critical, in the suppression condition compared to the control. This study is the first (to our knowledge) to test the idea that emotion suppression can strengthen shared physiological states (i.e., linkage) between partners. We found that physiological linkage was stronger under parent emotion suppression, albeit in different ways for mothers and fathers.

The growing body of work from our labs on affect contagion in child-parent dyads provides insight not only into the processes that are most likely to facilitate physiologic synchrony, but also, its boundary conditions. Mother-child dyads demonstrated the most consistent effects across all age ranges of children (from infants to eleven-year-olds). Mothers who experienced stress leading into an interaction had children who became synchronized with them (In Waters et al., 2014, 2017) and children whose physiology became causally associated with theirs (Waters et al., 2020)—an effect that was strengthened by mothers' attempts at emotion suppression.

However, even in these dyads, affect contagion was somewhat "task dependent"—in some cases, showing the strongest effects early on in the re-union between parent and child (especially when eye contact was allowed, as in the "no touch" condition in Waters et al., 2017, and during the conflict conversation in Waters et al., 2020, which was the first interaction to take place after reunion), and in others strengthening over time (as in Waters et al., 2014). Given this heterogeneous pattern, more work is needed to specify the conditions under which affect contagion will increase, and when it will decrease. To answer this question will no doubt require a more nuanced understanding of the range of behavioral cues people have access to and attend to during dyadic encounters—cues like eye contact, touch, tone of voice, and even complex behaviors like physical withdrawal—as well as high-level psychological processes, like motivation to attend to a partner, and the cognitive resources to do so. An understanding of the "actor level" behaviors and "partner level" psychological processes that facilitate affect contagion is not only essential to understanding physiologic synchrony in one of the most basic human relationships—the parent-child one—but also, in new acquaintance ones. Next, we dive into our program of research on moving beyond close-other dyads.

3.2 Affect contagion between new acquaintances

Our earliest studies demonstrated evidence for affect contagion in close other dyads, with a focus on experimentally manipulating the valence of affect (positive or negative), the intensity of affect, and the behavioral cues (such as touch, eye contact) which might facilitate affect contagion. But in many everyday interactions—from chatting with new colleagues in the workplace to meeting new neighbors or college roommates—affect might spread between two people who do not share a close, intimate bond. In our next line of studies, we focused on the factors that might moderate affect contagion (and more specifically, physiologic linkage) between new acquaintances. At the start of this work, the study of physiologic synchrony was largely dominated by the close relationships literature, but we theorized that even people who do not know each other well can potentially "catch" others' affective states—and that social factors, such as how similar people are to their dyad partners, may facilitate affect contagion.

3.2.1 Intra- and inter-racial dyads

One primary line of work focused on dyads in which we varied how similar people were to their partners on a variety of social category variables. In our first study to examine this question (West et al., 2017; see for data and annotated syntax https://tessawestlab.hosting.nyu.edu/lab-resources.html), we examined physiologic linkage between newly acquainted same-race (European American [EA]–European American) and cross-race (African American [AA]–European American) dyads, with a focus on how attention-grabbing behaviors, such as those associated with interracial anxiety (e.g., fidgeting and avoiding eye contact), when expressed by European Americans to African American partners, would facilitate physiologic linkage to EA partners. We reasoned that for African Americans, vigilance during interracial interactions is linked to motivation to detect bias across contexts. Indeed, racial minorities are adept at detecting racial bias, expressed through tone of voice, speech hesitancies, and physical gestures (Dovidio, Kawakami, & Gaertner, 2002). In contrast, European Americans may be less focused on behavioral signals of bias in their African American partners because these EAs tend to focus on being likeable (and non-prejudiced) than on being the target of prejudice (Gray, Mendes, & Denny-Brown, 2008; Richeson & Shelton, 2005). In same-race encounters, behaviors that signal anxiety, which are arguably subtle and often difficult to interpret, may not be perceived as negatively as they are in cross-race ones, and so individuals in these encounters may be less attuned to them (West et al., 2014).

Participants were new acquaintances who were either randomly assigned to have an interracial (AA-EA) or intra-racial (EA-EA) interaction. Dyads completed a series of cooperative tasks designed to vary in affective intensity and cognitive demand, which thereby allowed us to test the extent to which participants tracked the ups and downs of the affective state of their partner.

The first task consisted of a "getting-to-know-you" conversation. Next, participants completed a task we designed that used tactile finger-spelling during which participants alternated spelling out words using American Sign Language (ASL; an ASL sheet was provided); but rather than seeing each other's hands, they placed their hands in a box and felt each other's hands to determine the words being spelled (see Koslov, 2010; Stern & West, 2014). The last task was a cooperative word-guessing game based on the game Taboo. In this task, participants took turns trying to get their partner to guess words, without being able to use any of five taboo words that were listed on their prompt cards (e.g., if the word to be guessed was "birthday," the clue giver could not say "happy," "anniversary," "candles," "cake," or "presents"). The participants received 25 cents for every word guessed correctly and lost 25 cents for each taboo word accidentally spoken. The game alternated so each participant had two turns as a guesser and two as a prompter.

We employed electrocardiography (ECG) and impedance cardiography to obtain measurements of sympathetic nervous system (SNS) activity, specifically Pre-ejection period (PEP). We examined physiologic linkage between partners (using the same method described above in Waters et al., 2020) to capture the direction of who's physiology predicts whose. We measured anxiety in three ways: using (a) cortisol reactivity to compare levels from before and after the interaction; (b) observer-rated nonverbal behaviors of tension during the social interaction; and (c) self-reported discomfort.

We found that consistent with hypotheses, anxiety when experienced by EAs influenced physiologic linkage to those partners, but only in cross-race dyads, and the relationship was asymmetric—European Americans' greater anxiety (measured with cortisol, behavior, and self-report) facilitated linkage of their African American partners, but African Americans' anxiety did not facilitate linkage of their European American partners (with data trending in the opposite direction). Specifically, African Americans showed stronger physiological linkage to their European American partners when those partners had higher cortisol reactivity, greater behavioral displays of tension, and higher self-ratings of interpersonal discomfort.

In interracial interactions in which European Americans experience negative affect, such as stress and threat, linkage for African Americans might reflect the tendency to "catch" stress from their partners. We proposed that one potential outcome of this affect contagion process is that African Americans who are chronically engaging with stressed partners and are particularly attuned to cues of stress may in turn experience elevated levels of stress as a result, which over time could accumulate to dysregulation. Given that African Americans were most physiologically linked to anxious European Americans, this study provides evidence that physiologic linkage can capture the process of affect contagion, even among new acquaintances. It also points to critical moderators of affect contagion: behavioral cues associated with anxiety, expressed by the "actor"—or the person who the partner is becoming physiologically linked to.

3.2.2 Social status differences in dyads

In our next line of studies, we focused on how actor and partner social status moderates affect contagion (and physiologic linkage more specifically). In line with our approach in West et al. (2017), in Tan et al. (2022) (under review), we focused on dyads in which the members had similar or different levels of social status, which we quasi-experimentally manipulated.

We focused on social status—defined with material resources or subjective states—because it shapes many components of high-level processes, like motivation to attend and expression of clear behavioral cues, that are involved in affect contagion. Individuals are more motivated to attend to high status individuals than low status ones (Erber & Fiske, 1984; Field, Healy, & LeBlanc, 1989), suggesting that a target's status affects the degree to which people are attuned to them (and in turn, become physiologically linked to them). As such, attention appears to be a fundamental social currency that is given to high-status individuals. We proposed that that higher status individuals will be more likely to drive physiologic linkage than lower status ones because they garner more attention from their partners than vice versa. Working in concert with this effect, low status individuals are more vigilant of their surroundings and the emotional reactions than higher status individuals (i.e., are "good perceivers"), and are more motivated to accurately detect the thoughts and emotions of higher status partners (Frable et al., 1990). For example, individuals lower in social status are more likely to engage neural circuitry involved in *mentalizing*—thinking about others thoughts and feelings—than individuals higher in social status (Muscatell et al., 2012). In addition to these main effects of "actor" and "partner" status on perception and behavior, respectively, we furthered proposed that the similarity of dyad partners' status might also shape the degree of affect contagion. Especially in rapport-building encounters, similarity (especially on social category memberships) is one of the strongest determinants of liking and rapport, especially among new acquaintances. To the extent that affect contagion in this rapport-building context reflects shared experiences and liking, we would expect similar (either low status-low status, or high status- high status dyads) to not only exhibit more rapport-building behaviors, but also, experience stronger physiologic linkage.

To test these ideas, in Tan et al. (2022) (in review), we implemented a quasi-experimental approach to examine how one's own and one's interaction partner's social status shapes the degree of physiological linkage between partners. First, we created a multidimensional measure of socioeconomic status, using a composite of annual household and personal income, the MacArthur Scale of Subjective Status (SSS; Adler et al., 1994), education, mother and father's highest education, and SES identification (Jackman, 1979; Vyas & Kumaranayake, 2006). Participants were categorized as relatively low status (a negative standard deviation) or relatively high status (a positive standard deviation). Then, we created two types of "same status" dyads (high status people with high status partners, and low status people with low status partners).

Dyads engaged in a series of different social interactions, including a cooperative game of Taboo and a speech task, beginning with a "SES signaling" question and answer session. SES can be conveyed rapidly and accurately to others through behavioral cues, such as physical appearances, mannerisms, and linguistic choices, as well as specific leisure activities and preferences (Bourdieu, 1984; Kraus & Keltner, 2009; Kraus, Park, & Tan, 2017). The 12 questions participants asked each other were designed to subtly reveal status, and included where they grew up, what school they last attended, and what their favorite restaurants and clothing stores were.

We found that lower SES participants showed stronger physiological linkage to their partners, including those who were both relatively low in status (similar to them) and relatively higher in status (different from them), compared to higher SES participants. These findings are consistent with our hypothesis that perceiver status is a "perceiver level" moderator of physiologic linkage, presumably because it influences high level processes, like motivation to attend to the partner. Importantly, the effects for physiologic linkage hold although participants in general showed stronger liking and perceived similarity toward similar status partners, as predicted. Moreover, higher SES participants appeared more dominant and less submissive than low SES ones, regardless of the status of their partners, consistent with work demonstrating a strong relationship between status and dominance. These findings are consistent with our theorizing that status not only shapes the behavioral cues we give off in social interactions, but also, that a perceiver's own status shapes how they attend to, and are physiologically influenced by, their partners.

While the SES study shed light on how individuals from different socio-economic groups interact and influence each other, SES level was measured, not manipulated, and so it remains unclear how much of the social standing differences are due to participants SES or to the many other factors that covary with SES. We tested direct effects of social standing using a sartorial manipulation using recently acquainted male participants (Kraus & Mendes, 2014). In this study, we recruited male participants and matched them in dyads based on similar race, ethnicity, age, and occupation. One member of the dyad was instructed to arrive 30 min earlier than the partner. Upon arrival, the first participant (Participant A) was instructed that we were studying social interactions and wanted to test wearable physiological sensors. Participants were then randomly assigned to one of three conditions. In the first two conditions, the experimenter brought in clothes in the participants size (we obtained this information in prescreening) that had faux physio sensors sewn into the clothing and were either (1) high-status clothing (suit, shirt, tie, dress shoes) or (2) low-status clothing (cheap sweats and sweatshirt, plastic shower shoes). The third condition allowed the participant to keep on their own clothing and had additional faux sensors attached. We then applied all the typical sensors to measure physiology. When the Participant B arrived, they were not informed of the clothing manipulation and simply interacted with Participant A.

After a resting baseline, the dyad and met and engaged in a competitive negotiation task which included one person acting as the seller of a property and the other participant as a buyer. They were individually told to try to maximize profits—seller to get the highest price, and buyer to purchase for a low price. In addition to measuring physiology and perceptions, we also obtained saliva that we assayed for testosterone, and we coded for behavior. Similar to the Tan et al. (2022) (in review) study, we observed strong effects for social status. Men randomly assigned to the high status clothing condition showed classic dominance behavior and negotiated for better profits than all other participants. Upper status clothing also resulted in their partners showing more vigilance (monitoring them for behavior) and reduced perceptions of power; more likely to show physiologic linkage—partners of high-status men also showed stronger physiologic linkage to their partners than did those of low status and control participants. Thus, high status clothing was associated with greater *influence* than lower status clothing or individuals' own clothing.

3.2.3 Social status differences in groups

Status is a powerful influence in real group settings, and our recent work has extended to study real world settings (del Rosario et al., 2022, in review). One setting in which social status is critical is in operating room settings where the hierarchy of the personnel is unambiguous. We examined linkage of operating room personnel in 16 unique surgeries of liver or renal transplants. These are long surgeries that vary in risk, which we defined as risk of intra-operative bleeding. Abdominal transplants which were considered either low-risk (arteriovenous fistula) or high risk (renal transplant or hand-assisted laparoscopic nephrectomy) operations (Singh & Zeltser, 2022).

Each surgery team was comprised of four people: an anesthetist, a senior surgeon, a junior surgeon, and a surgical nurse. We obtained measures of IBI for the senior surgeon, junior surgeon, and surgical nurse for the duration of the surgeries (but not the anesthetist, who typically left the operating room during the surgery after the patient was anesthetized). In the operating room, the senior surgeon is the highest status member of the team, and the affective expressions and feelings of the senior surgeon can dramatically shape the tenor of the operating room. For example, one study found that 82% of junior surgeons reported feeling that the senior surgeon's mood dictated the effectiveness of communication in the operating room, illustrating that hierarchy among medical teams is salient (Grade, Tamboli, Bereknyei Merrell, Mueller, & Girod, 2019).

We were interested in the extent to which linkage would occur among the operating room personnel and if this were more likely to occur during high-risk surgeries. We observed significant covariation for the entire team, but low risk and high risk surgeries differed from each other. During low-risk surgeries, senior surgeons and nurses showed strong and positive covariation. In contrast, during high risk surgeries, senior surgeons showed greater SNS reactivity, and the *greater* their SNS reactivity the *less* reactive the other members of the surgical team. This is one of the few studies during which we observed negative covariation within a context of a "cooperative task." We speculate that the more engaged senior surgeons may be providing a signal to other operating room personnel that the task is being handled creating a type of off-loading of the psychological burden. While this is highly speculative, this work shows the need to study real world groups.

In our next line of studies, we shifted from examining how social category memberships alone shape affect contagion, to studying some of the behavioral processes that are most likely to facilitate it. More specifically, we tested the possibility that we can manipulate whether someone is a "good sender" in social interactions—that certain behaviors, when turned "on," can facilitate physiologic linkage. In Thorson, Dumitru, Mendes, and West (2021a) we examine whether physiological linkage from "senders" to "receivers"—which occurs when a sender's physiological response predicts a receiver's physiological response—is associated with senders' success at persuading a group to make a decision during a group decision making task that aligns with their own self-interest. In small groups of five, we randomly assigned two members to try to convince the group to make a particular decision (chose a specific job candidate among a slate of them). We then examined whether the individuals who were successful at the job had stronger physiologic linkage to them than those who were unsuccessful. We also introduced a status manipulation to examine whether high-status successful persuaders had stronger physiologic linkage to them than low-status ones or whether status trumped persuasive ability in predicting linkage. Thus, we were able to pit two different "partner level" moderators against each other: status, and persuasive skill.

In groups of 5, we randomly assigned 1 person to be high status, 1 low status, and 3 middle-status (based on bogus feedback to a leadership questionnaire; Anderson & Berdahl, 2002; Galinsky, Gruenfeld, & Magee, 2003; Lammers, Galinsky, Gordijn, & Otten, 2008). Groups completed a collaborative decision-making task that required them to come to a consensus on a decision to hire 1 of 5 firms. Unbeknownst to the 3 middle-status members, the high- and low-status members surreptitiously were told to each argue for different firms. In other words, they were assigned to try to convince the group to make a decision that aligned with their self-interest. We measured cardiac interbeat intervals of all group members throughout the decision-making process to assess physiological linkage.

We found one variable associated with physiological linkage: regardless of their status, those who were successful at persuading the group to make a decision that aligned with their self-interest were more likely to have group members who showed physiological linkage to them, throughout the task. This finding suggests that successful persuaders are good "senders"—and that linkage is associated with an outcome—winning a persuasion exercise.

Experimentally manipulated status, on the other hand, was unrelated to physiological linkage. This finding contrasts with our prior research showing that higher status people typically garner the most attention, and our own work demonstrating that lower status individuals show stronger physiological linkage to their partners than high status ones. Returning to Fig. 2, it may be the case that variables associated with physiologic synchrony are hierarchical in nature, with some variables trumping others, once considered in combination. For example, factors related to a sender's ability to capture the attention of a group may trump a sender's social status in shaping physiologic synchrony. Interestingly in Thorson, Dumitru, Mendes, and West (2021a), experimentally manipulated status did reliably map onto behaviors typically associated with status in other studies (including talk time and dominance, with high status people talking more, and appearing more dominant), suggesting that the manipulation worked as intended. However, these behaviors were not associated with successful persuasion, and they might not have grabbed group member's attention during the task. Future work should test whether these findings replicate in real-world groups, in which status is conferred naturally. Behaviors associated with high status in these groups are often similar to the behaviors associated with being a successful persuader: holding the floor, asserting your leadership early on, for example. In real world groups, we would expect higher status team members to garner more attention than low status ones, as we found in our other work.

In another study with a similar method (Thorson, Dumitru, & West, 2021b), we modified the paradigm used in Thorson, Dumitru, and West (2021b) whereby individuals in groups of three or four selected one of five search firms in a mock firm search. Rather than have two individuals compete with each other for attention from the group (in an effort to get the group to make a decision that aligned with theirs), we only assigned one person to try to convince the group, thereby removing the competitive element. In all groups, one woman was randomly assigned to have higher status than her groupmates; she was also surreptitiously instructed to persuade her group to select one (randomly assigned) firm. The most notable difference between this study and Thorson, Dumitru, and West (2021b) is that we did not introduce competition between two team members; only one person was tasked with convincing the group. As in Thorson, Dumitru, and West (2021b), we measured cardiac interbeat intervals for participants throughout the decision-making process to assess physiological linkage—the degree to which a "sender's" physiological response predicts a "receiver's" physiological response at a subsequent time interval. Participants were students at NYU Abu Dhabi, and incredibly diverse in terms of their ethnic and national group memberships.

What we found surprised us. We did not replicate Thorson, Dumitru, and West (2021b), in which successful persuaders had group members who showed stronger physiologic linkage to them. Rather, we found that successful persuaders were better perceivers–they had stronger physiologic linkage to their group members. The stronger the physiological linkage to their group members, the more likely they were to successfully persuade the group. Taken together with Thorson, Dumitru, and West (2021b), these data demonstrate that the same variable–successfully persuading a group–is associated both with being a sender (especially in situations in which competition over attention is invoked) and being a good perceiver. These are the first studies to our knowledge to show that the very same variable can operate on the perceiver side to moderate physiologic linkage in one setting (one without competition) and operate on the sender side in another (one that includes competition).

3.3 Moderators of affect contagion

We view affect contagion as happening relatively naturally within dyads and groups. We were especially interested in testing some of the ideas of affect contagion within groups with repeated exposure to each other. This led to the idea of directly manipulating a group's ability to perceive and express engaging in group interactions. In Thorson, McKernan, West, et al. (2021c), we tested whether oxytocin—a neuropeptide that can enhance expressivity and social perception—influences physiologic linkage of autonomic nervous system responses among patients with methamphetamine use disorder (MUD) and their facilitators during group therapy. The setting was highly emotive; ideal for studying the process of affect contagion among group members. Participants were in cohorts made up of four to six people engaged in six weekly group therapy sessions. Prior to therapy, all participants of a cohort received oxytocin or placebo intranasally in a randomized double-blind procedure before each session.

Methamphetamine is a highly addictive potent psychostimulant, which can impair social perception. For example, methamphetamine users struggle with accurately detecting emotions in others and inferring the intentions of others (Homer, Halkitis, Moeller, & Solomon, 2013; Kim, Kwon, & Chang, 2011; Payer et al., 2008; Potvin et al., 2018). We reasoned that oxytocin may facilitate physiological linkage because it acts on both "target" level and "perceiver level" processes. Not only can oxytocin heighten sensitivity to social signals, suggesting that it can improve people's ability to attend to other's expressions, but it is also associated with increases in expressiveness of facial and vocal signals of emotion (Spengler et al., 2017; Woolley et al., 2017), suggesting that it can also improve people's ability to be good targets. Thus, we reasoned that oxytocin may enhance physiological linkage between people by promoting greater expressiveness on the part of the sender and greater perceptiveness on behalf of the receiver.

Importantly, oxytocin does not always improve social perception, and the strength and direction of oxytocin's effects on social perception can vary widely depending on individual characteristics and social context (Bartz, Zaki, Bolger, & Ochsner, 2011; Fischer-Shofty, Levkovitz, & Shamay-Tsoory, 2013; Kanat, Heinrichs, & Domes, 2014; Lynn, Hoge, Fischer, Barrett, & Simon, 2014; Israel, Hart, & Winter, 2014). The ability of oxytocin to facilitate social perception and expression tends to be limited to positive social encounters (e.g., those in which affiliative behaviors are expressed; Cardoso, Kingdon, & Ellenbogen, 2014; Domes et al., 2013; Gamer, Zurowski, & Büchel, 2010; Guastella, Mitchell, & Dadds, 2008). Group therapy is a supportive, client-centered context, making it an ideal place to examine the facilitative effects of oxytocin on physiologic synchrony. Cardiac interbeat intervals (IBI) were measured continuously during sessions to estimate physiological linkage, operationalized as one cohort mate's IBI reactivity during 1 min predicting another cohort-mate's IBI reactivity during the following minute. Fig. 3 illustrates how linkage relationships were conceptualized with this repeated-measures group data. In oxytocin cohorts, participants and facilitators experienced significant physiological linkage to their cohort-mates (i.e., their physiological responses were predicted by the prior responses of their cohort-mates)

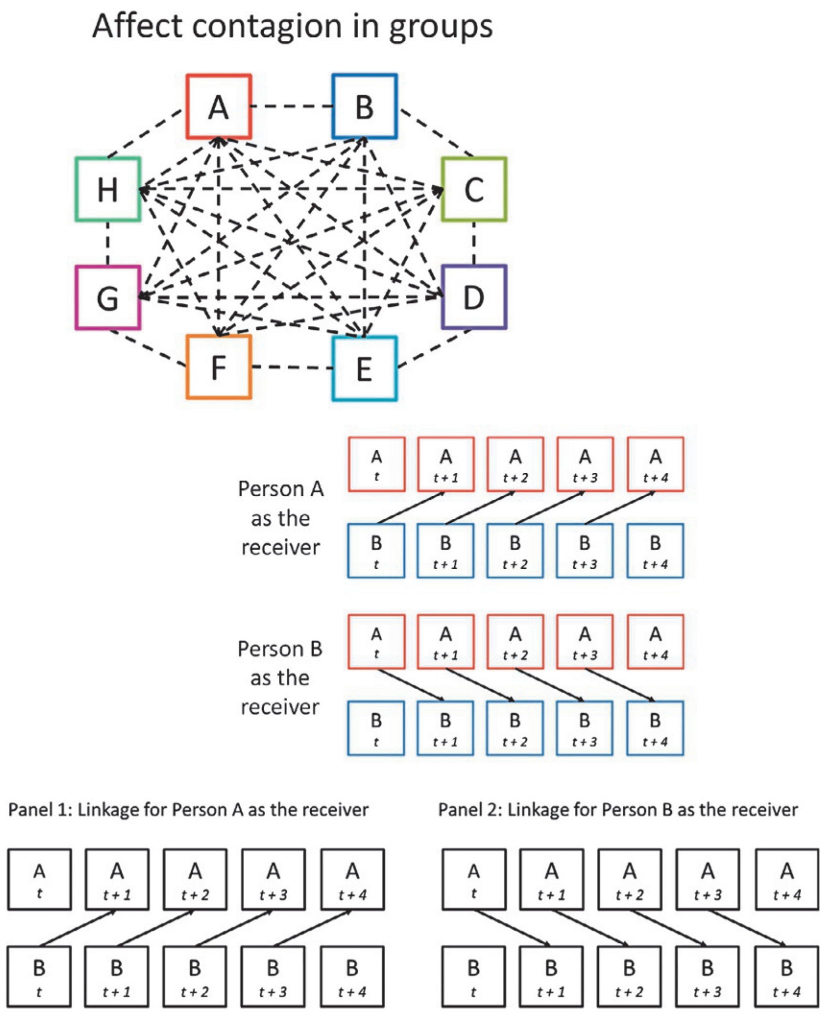

Fig. 3 Model of affect contagion in group settings.

and significantly more linkage than people in placebo cohorts. Both effects occurred during the first and second sessions but not later sessions. Results suggest that oxytocin may enhance psychosocial processes often associated with linkage, such as social engagement, and highlight oxytocin's potential to improve group cohesion during group therapy.

In other work, we have examined whether individual differences related to perceptibility—emotional empathy more specifically—not only facilitates affect contagion, but also, accuracy in reading a partner's emotional states. Empathy is a multidimensional construct that encompasses our ability to share, understand, and respond appropriately to others' emotions (Decety & Jackson, 2004). Dispositional emotional empathy refers to the tendency to share others' emotions (i.e., feeling what someone else feels). Individuals high in emotional empathy are more likely than individuals low in emotional empathy to share and embody a partner's emotions (including partner's distress and negative affect) and respond appropriately to other's distress (Davis, 1983). Thus, empathy might represent a "perceiver level" variable that affects the degree to which individuals are influenced by their partners' affective states, and show physiologic linkage to them.

In Brown et al. (2021), one partner (the experiencer) underwent an intense emotion induction designed to be visceral and distressing; they watched a series of emotional films designed to elicit negative emotion including Trainspotting, American History X and Dogtooth, while engaging in disgusting behaviors, including drinking what appeared to be dirty water with a cockroach ice cube (the cockroach was fake, as was the "dirt"). The emotion induction occurred away from the other participant (the listener), who went through a relaxing task (they watched an Appalachian Trail video).

After it was over, the two partners were united, and the experiencer went through the Trier Social Stress Test, while the listener watched. Next, the experiencer was instructed to share their negative personal experiences with the listener, with some help from the listener, who was handed cue cards with questions on them meant to prompt recall of the experience. Following these tasks, both people privately rated their own emotions during the TSST and the dyadic interaction. We then had participants watch a feedback video of the interaction and rate their perceptions of their partners emotions using a dial rating system, which allowed us to examine accuracy in reading one's partner's emotional states. We examined linkage of PEP using the method described above (see West et al., 2017).

We did not find evidence that listeners were more physiologically linked to experiencers, or that those high on empathy were more accurate. Rather, we found that among those high in empathy, physiologic linkage was more strongly and positively associated with accuracy—being linked to a partner was associated with accurately reading that partner's states. One explanation for this finding is that highly empathic people know what behavioral cues to attend to in their partners: they understand which behaviors are associated with different emotional states, and therefore the "linking up" to their partner's physiology captures that attention process. Another possibility is that listeners higher in emotional empathy are influenced by their distressed partner's SNS arousal if they have better accuracy in identifying their distressed partner's emotions. The direction of causation is hard to identify in this study, and more work is needed to test whether accuracy leads to physiologic linkage, or vice versa.

3.4 Affect contagion during low arousal affective states

Thus far, most of the studies we have discussed have examined the degree of affect contagion with high arousal emotions, such as anxiety (with some exceptions, see Waters et al., 2017, where we manipulated low arousal positive affect), and general negative arousal (Brown et al., 2021). In del Rosario et al. (2022), we tested the question: can low arousal negative emotions—sadness in particular—be transmitted during social encounters between new acquaintances? And when these emotions are experienced prior to an interaction, how do they manifest behaviorally?

We proposed that high and low arousal emotions manifest differently behaviorally in ways that can shape the process of affect contagion. High arousal emotions, like stress, generate greater sympathetic activation to prepare the body to act, consequently producing clear behavioral signals of distress (Kreibig, Wilhelm, Roth, & Gross, 2007; Lang, Levin, Miller, & Kozak, 1983). In contrast, low arousal emotions are characterized by withdrawal and inactivity (Blascovich & Katkin, 1993; Kelsey, Ornduff, Reiff, & Arthur, 2002), which for sadness includes withdrawal from strangers (Leschak & Eisenberger, 2019). In dyadic interactions where the experience of sadness is felt *outside* of the interaction (in this case, prior to it), people may not give off clear signals sadness per se (spoiler alert: they did not appear sad in our study), but rather, engage in behaviors that signify passive coping—smiling and gesturing less—for example, than they would if they did not feel sad walking into the interaction. Situations such as these are common in contexts like the workplace, where emotion inductions happen (e.g., people learn sad personal new), but disclosure of those emotions to an interaction partner are either not relevant to the social interaction, and people do not feel appropriate to act on their emotions (e.g., crying in a meeting following sad personal news).

We proposed that in interactions with new acquaintances, people who experienced a sadness manipulation prior to the interaction will disengage more from their partners than those who experienced a neutral (non-emotion) manipulation. In other words, sadness, felt prior to an interaction, will manifest as disengagement during it. As a result of this disengagement, we expected the "sad" individuals to display fewer attention-grabbing behaviors that facilitate social interactions—smiling and gesturing in particular—which in turn, would lead weaker physiological linkage to them. In Fig. 2, we think of these behaviors as those that make a target less "readable" to their partners, thus moderating the degree of physiologic linkage. We did not predict that people in the sad induction condition necessarily appear sad—crying, displaying clear signs of emotional distress or despondence, for example—because the tasks they completed with their partner included a getting-acquainted conversation, and a game of the word guessing game Taboo. Neither of these tasks were designed to reignite the sad feelings participants felt during the emotion induction manipulation. Thus, this is one case in which "emotion contagion" was not predicted to be a straightforward transference emotion, but rather, that the emotional state would influence the degree to which people were able to capture the attention of their partners.

As a secondary question, we examined whether the moderating effect of the sadness manipulation on physiological linkage and behavior would hold for both male-male and female-female dyads (all dyads were same-gender and included only those who self-identified their gender as male or female). Women are generally perceived as more emotionally expressive and thought to have a more emotional disposition than men (Barrett & Bliss-Moreau, 2009; Barrett, Robin, Pietromonaco, & Eyssell, 1998; Kring & Gordon, 1998), although both men and women are similarly emotional (for review see Nolen-Hoeksema, 2012). However, societal norms may lead men to avoid expressing vulnerable emotions such as sadness (Barrett, 2006; Cassano, Perry-Parrish, & Zeman, 2007; Levant et al., 2007), and potentially overcompensate for them (Chaplin, Cole, & Zahn-Waxler, 2005).

Here, we proposed that men may overcompensate for their feelings of sadness by appearing even more engaged—smiling more and gesturing more—than men who did not experience sadness. Indeed, in our prior work, we have found evidence that in getting acquainted interactions, interaction partners will overcompensate for negative emotions by bending over backwards by appearing "super engaged." Specifically, Mendes and Koslov (2013) found that in an effort to suppress their anxiety over trying to appear non-biased during interracial interactions, Whites exhibited a "brittle smiles" effect—they displayed overly positive behaviors to their partners, but had heightened sympathetic nervous system reactivity.

To test these questions, American adults with varying race and ethnicity ($N = 230$) were recruited and then matched with a same-sex/same-race partner. One of the dyad members was randomly assigned to be an actor (whose affective state was manipulated), whereas the other was assigned to be a partner (whose affective state was not manipulated). For the lab visit, the actors were asked to arrive earlier than the partners and were then randomly assigned to recall an experience from their past when they felt extreme sadness (sadness condition) or a mundane experience (neutral condition), following a modified procedure from Ayduk and Kross (2010). Immediately after the affect manipulation, the dyad met and engaged in a getting acquainted conversation, following a game of Taboo (similar to West et al., 2017). To capture the various dimensions of emotion and social attention, we employed a multimethod approach assessing physiologic linkage of PEP (consistent with West et al., 2017), behavioral displays of engagement, language coding (for the emotion induction), and self-reported emotion. Engagement behaviors included gesticulating during the conversation, maintaining an open posture, and smiling, which signal engagement and draw attention from interaction partners. We also examined the use of affective language by using a combination of natural language processing and trained human coders to assess whether there were differences in how men and women described sad (or neutral) events during the manipulation. Finally, we examined self-reported emotion as a subjective measure of sadness. These measures provide a rich picture of how emotions shape social interactions using a full suite of behaviors.

First, we examined how men and women responded to the sadness induction (relative to the neutral condition). In examining the affective language used by participants, those in sadness condition unsurprisingly expressed more negative emotions than those in the neutral condition, and men and women used equal amounts of negative words (based on sentiment analyses). However, we were surprised to find that men in the sad condition were rated as more emotionally intense by human coders than women and were perceived as more distressed, despite women reporting feeling sadder than men. These findings suggest that either the sentiment analyses were not able to pick up on all possible emotion-based cues (those expressed paraverbally, such as tone of voice, shakiness), or that human coders were viewing the responses through a stereotype-based lens of how men and women are expected to express. Despite extensive training of coders, it is impossible to rule this possibility out, given that they were aware of the gender of the participants.

Importantly, we also found that the sadness induction impacted behavior and physiology differently for male-male and female-female dyads. Sadness-induced women smiled less relative to their partners and control dyads (where both were in the neutral induction condition), whereas sadness-induced men gestured and smiled more throughout the interaction compared to male partners and dyads in the control condition. Moreover, female sad dyads did not exhibit physiologic linkage whereas female control dyads did show linkage. Conversely, all male dyads showed positive linkage and the partners of the sadness-induced men showed the strongest linkage.

Taken together, sad-induced men appeared the most engaged, and they had the stronger physiologic linkage to them. These findings are the first to our knowledge to show gender differences in affect contagion among newly acquainted same-gender dyads, and how the same emotion induction can manifest behaviorally, and physiologically, quite different for men and women.

4. Future directions

For over a decade we have studied affect contagion, using peripheral psychophysiology, as a broad phenomenon; it occurs across social contexts—from getting acquainted chats, conflict conversations, to decision-making tasks—and across relationship types—from child-parent pairs and newly acquainted dyads to small teams. Affect contagion can occur when affect is negative (stress, disgust, and sadness) and positive (calm), and varies in intensity from strong to weak. Physiologic synchrony is a broad phenomenon, and our initial work has provided a strong foundation on which to dive deeper into the processes that underlie it.

One goal of our future work is to isolate the high-and-low-level factors that facilitate affect contagion. We have isolated a few of these factors in our studies (e.g., touch in mother-infant relationships, the motivation to capture attention of group members in teams), but a more systematic examination of these factors should be done. The study of interpersonal accuracy can provide a useful guide for how to move forward. For example, we could apply a Brunswik Lens model approach to understanding which behavioral cues make individuals "good targets" and "good perceivers" (similar to Funder's, 1995, approach to studying accuracy). We have hypothesized that low-level cues such as tone of voice, odor, and shared environmental cues like crowd size and temperature likely shape the degree of shared physiologic experience, and these factors might facilitate the process of affect contagion. Future work could isolate these cues to determine which are most essential (and how and when different cues cancel each other out). High-level cues associated with rich psychological processes, such as perspective taking, empathy, and motivation, are critical to understanding what makes someone a "good perceiver"—that is, what makes them likely to "catch" the emotions of others. In the terminology of Funder, cues need to be both valid (represent the actual emotion people are experiencing) and utilized (perceived by the interaction partner) for them to facilitate accuracy. These processes might similarly affect contagion—cues need to be clearly expressed and perceived in order for them to shape contagion of specific affective states. In addition, we have hypothesized in our model that a physiologic linkage approach is most appropriate when there are specific "target" and "perceiver" processes thought to underlie affect contagion; there is one partner whose psychological experiences are thought to facilitate contagion, and another whose behaviors are thought to facilitate it. Determining how these target and perceiver processes intersect is a direction that we plan to take.

Another important direction is to move beyond the laboratory environment to capture affect contagion in "real world" settings. While the lab provides much needed precision to the study of affect contagion, we are limited in the conclusions we can draw from what occurs within it. We have begun some of this work by examining affect contagion in small surgery teams conducting transplant surgeries (del Rosario et al., 2022).

Lastly, the majority of our work has been conducted in dyadic interactions (with a few exceptions), but many naturalistic encounters are more complex. For example, some of our on-going work is examining the process of affect contagion when newcomers join teams. The strength of affect contagion between the existing members might affect the degree to which the newcomer "catches" emotions from their new team. Fig. 3 illustrates how we conceptualized the study of affect contagion for Thorson, McKernan, West, et al. (2021c), in which small groups of people interacted with a therapist. We could extend this conceptualization to other small groups, where the strength of affect contagion between any two members is estimated and potentially treated as a predictor of the strength of affect contagion between new team members. In situations like the workplace where teams are constantly changing as people resign and on-board, understanding affect contagion as a process that shifts over time as people move in and out of teams is an important direction for future work.

In summary, while our current work provides a strong foundation for the study of affect contagion, there are many new and exciting directions this work can go. And although they are time consuming, expensive, and exhausting, we argue that they provide insight into the dynamics of social interactions difficult to estimate with other approaches.

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ADVANCES IN EXPERIMENTAL SOCIAL PSYCHOLOGY

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