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Families that fire together smile together: Resting state connectome similarity and daily emotional synchrony in parent-child dyads

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ABSTRACT

Despite emerging evidence suggesting a biological basis to our social tiles, our understanding of the neural processes which link two minds is unknown. We implemented a novel approach, which included connectome similarity analysis using resting state intrinsic networks of parent-child dyads as well as daily diaries measured across 14 days. Intrinsic resting-state networks for both parents and their adolescent child were identified using independent component analysis (ICA). Results indicate that parents and children who had more similar RSN connectome also had more similar day-to-day emotional synchrony. Furthermore, dyadic RSN connectome similarity was associated with children's emotional competence, suggesting that being neurally in-tune with their parents confers emotional benefits. We provide the first evidence that dyadic RSN similarity is associated with emotional synchrony in what is often our first and most essential social bond, the parent-child relationship.

Introduction

The human mind is continuously coupled to those around us, and this shared social synchrony influences the way we perceive, respond to, and thrive in a complex social world (Wheatley et al., 2012). As far back as 384 BC, Aristotle described human nature as inherently social (Saunders, 1995 trans.), and scientists today describe humans as wired to connect with others (Lieberman, 2013; Schilbach et al., 2013; Wheatley et al., 2012; Wiltermuth and Heath, 2009). Indeed, social synchrony appears in infants as young as one-day-old (Singer, 2006), suggesting that humans are biologically prepared to connect with others (Feldman, 2007b), and is found across species including mice (Langford et al., 2006), suggesting that synchrony is evolutionarily conserved. Despite emerging evidence suggesting a biological basis to our social tiles, our understanding of the neural processes which link two minds is unknown.

Although social synchrony is found across many forms of human relationships, synchrony occurs most with similar or close others, a phenomenon found in humans and mice (Langford et al., 2006). From an evolutionary perspective of parenting in mammals, parents and their child are wired to connect, which promotes survival (De Waal, 2007). Social synchrony in mother-child dyads includes the coordination of ongoing exchanges of sensory, hormonal, and physiological stimuli between parent and child and ranges from the initial consolidation of biological rhythms during pregnancy to the emergence of complex social and emotional exchanges between parent and child throughout development (Feldman, 2007a, 2007b; Rosenblatt, 1965; Schneirla, 1946). Given the protracted dependence of humans on their parents, coordinated social synchrony may be co-opted into childhood and adolescence, ultimately providing the foundation for youth to develop socioemotional competence. Indeed, dyadic synchrony influences emotion regulation and adjustment (Barber et al., 2001) such that coherence of emotional states between parents and children (e.g., shared affect) provides critical inputs for youths' social and emotional well-being (Feldman, 2007a, 2007b; Feldman et al., 1999).

Significant work has begun to examine the biological underpinnings of parent-child dyadic synchrony, such that physiological arousal (e.g., heart rate) (Feldman et al., 2011) and hormonal levels (e.g., cortisol levels) (Papp et al., 2009) are frequently in-synch between parents and their child. For instance, during free-play, mothers' and infants' heart rates become synchronized, and during stressful events, infants who engage in more synchronous interactions with their mothers show better autonomic regulation (Feldman, 2007b). Despite these exciting advances in the field of dyadic synchrony, we know relatively little about how two minds are coupled. If indeed, the human mind is wired to connect, then an exciting new research direction is to test whether

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parents and their children show similar patterns of neural connectivity.

In the current study, we examined how neural connectivity patterns are shared between parents and their child. We implemented novel statistical and methodological techniques to examine how similarity between parent-child intrinsic resting-state network (RSN) connectivity is associated with day-to-day emotional synchrony. Moving beyond the individual, resting state functional magnetic resonance imaging (rs-fMRI) was administered for both parents and children. Rs-fMRI provides an ideal method for examining the neural connectome, as it assesses the strength of multiple intrinsic functional neural networks, networks active and synchronized when the brain is at rest independent of stimulus-induced brain activity usually driven by experimental demands (Cole et al., 2010; Uddin et al., 2010). Intrinsic resting-state networks for both parents and their adolescent child were identified using independent component analysis (ICA). Parent-child dyads also completed daily diaries, in which they indicated their daily mood each evening for two weeks. From these daily diaries, we were able to capture parent-child emotional synchrony, or the extent to which their mood fluctuated together day-by-day. We examined how dyadic connectome similarity is associated with the quality of daily emotional synchrony and whether the association between brain similarity and daily emotional synchrony confers benefits to adolescents' emotional competence. We hypothesized that greater similarity of intrinsic functional connectome in parent-child dyad would increase daily emotional synchrony and be linked to adolescents' emotional well-being.

Methods

Participants

As part of a larger study, we recruited 76 participants (37 adolescent children and 39 primary caregivers). All participants provided informed consent/assent, and no participants reported any mental health problems (e.g., current clinical diagnose or pharmacological intervention for a mental illness). Among all participants, 31 parent-child dyads (n=62) successfully completed the dyadic resting state scan (parent M_{age}=43.06 years, range=33 – 57, 12.90% father; child M_{age}=14.80 years, range=13–17, 48.39% female). All parent-child dyads were biologically related and provided written informed consent/assent. No participants were excluded due to excessive motion (i.e., mean framewise displacement, FD > 0.5 mm) or reported any mental health problems (e.g., current clinical diagnose or pharmacological intervention for a mental illness).

Procedures

Adolescent children and their primary caregiver completed a brain scan during which resting state was acquired. Children and their parent also completed daily checklists for 14 days. Participants either completed the checklists by accessing a secure website or by using pencil and paper. For those completing with paper/pencil, we monitored completion of the checklists by providing participants with fourteen manila envelopes and an electronic time stamper. The time stamper is a small, hand-held device that imprints the current date and time and is programmed with a security code so that the correct date and time cannot be altered. Participants were instructed to place their completed checklists into a sealed envelope each night and to stamp the seal of the envelope with the time stamper. For those completing the surveys on the secure website, an email with the link to each daily survey was sent separately to the parent and child, and the time and date of completion were monitored via the website. In addition to the daily diaries, parents and children completed a questionnaire, which included adolescents' emotional competence, as well as several measures as part of the larger study and published elsewhere (e.g., Lee and Telzer, 2016).

Questionnaires

Daily emotional synchrony

Children and their parents each completed daily checklists for two weeks (a total 14 daily measures). Each night before going to bed, participants responded to three questions about their positive mood (e.g., "joyful" "calm" "happy") and 10 questions about their negative mood (e.g., "sad" "hopeless" "discouraged" "uneasy") using a five-point scale (1="Not at all" to 5="Extremely"). From these 14 daily measures, we first calculated the daily concordance between adolescents' and parents' mood. The mood concordance for each dyad was estimated by predicting children's daily mood from parents' daily mood that day (positive and negative coherence, respectively). Given the nested nature of the data, we used Hierarchical Linear Modeling (HLM) which was designed to analyze nested data of the type that were collected for this study (i.e., daily level data nested within individuals) as follows:

$$\text{child's daily mood}_{ij} = b_{0j} + b_{1j}(\text{parent's daily mood}) + e_{ij.}$$

Mood on a particular day (i) for a particular child (j) was modeled as a function of the average mood of the children across days (b_{0j}) and the parent's mood that day (b_{1j}). Separate models were run for positive and negative mood, and the empirical Bayes estimate for each dyad over the 14 days was extracted from each of the statistical models. The empirical Bayes estimate is an optimally weighted average that combines the dyad's average slope and "shrinks" it towards the mean slope of the group (Diez, 2002) for each mood category such that higher values indicate higher concordance between parent and child for a given mood. Finally, we calculated an emotional synchrony index between parents and children by subtracting the concordance score of negative mood from the positive mood concordance score such that higher values represent more synchronized daily emotion between parents and their child toward positive mood and away from negative mood. On average, parent's daily mood did not predict children's daily mood (B=0.14, SE=.01, p=.10). However, there was significant variability in parent-child emotional synchrony (M=−0.10, SD=0.66, range=−1.25 to 0.66), indicating that some families are desycnronous and others are highly synchronized. Three adolescent children did not complete the daily checklists.

Child's emotional competence

Emotional competence was measured using the Toronto Alexithymia Scale (Bagby et al., 1994). Using a five-point scale (1="strongly disagree" to 5="strongly agree"), adolescent children responded to 20 items examining (1) *difficulty in identifying feelings* (e.g., "When I am upset, I don't know if I am sad, frightened, or angry"); (2) *difficulty in describing feelings* (e.g., "It is difficult for me to find the right words for my feelings"), and (3) *external-oriented thinking* (e.g., "I prefer to just let things happen rather than to understand why they turned out that way"). The 20 items were summed and reverse scored (Telzer et al., 2014), such that higher scores indicate greater emotional competence. The scale's internal consistency was α=.72. We failed to get responses from four adolescent children.

Resting-state fMRI (rs-fMRI)

Data acquisition, preprocessing

Participants completed a 6-min resting state scan, during which they were instructed to view a black screen with a white fixation cross. All imaging data were collected using a 3T-Siemens Trio MRI scanner with a 32-channel matrix coil. High-resolution structural images (T1-MPRAGE) were acquired first (repetition time or TR=1.9 s, echo time or TE=2.3 ms, matrix size=256×256, field of view or FOV=230 mm, flip angle or FA=90°, 1 mm isotropic voxel). The resting-state data were acquired from a gradient-echo echo-planar image sequence. The