

Child Gender Influences Paternal Behavior, Language, and Brain Function

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Multiple lines of research indicate that fathers often treat boys and girls differently in ways that impact child outcomes. The complex picture that has emerged, however, is obscured by methodological challenges inherent to the study of parental caregiving, and no studies to date have examined the possibility that gender differences in observed real-world paternal behavior are related to differential paternal brain responses to male and female children. Here we compare fathers of daughters and fathers of sons in terms of naturalistically observed everyday caregiving behavior and neural responses to child picture stimuli. Compared with fathers of sons, fathers of daughters were more attentively engaged with their daughters, sang more to their daughters, used more analytical language and language related to sadness and the body with their daughters, and had a stronger neural response to their daughter's happy facial expressions in areas of the brain important for reward and emotion regulation (medial and lateral orbitofrontal cortex [OFC]). In contrast, fathers of sons engaged in more rough and tumble play (RTP), used more achievement language with their sons, and had a stronger neural response to their son's neutral facial expressions in the medial OFC (mOFC). Whereas the mOFC response to happy faces was negatively related to RTP, the mOFC response to neutral faces was positively related to RTP, specifically for fathers of boys. These results indicate that real-world paternal behavior and brain function differ as a function of child gender.

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A number of studies argue that parents treat girls and boys differently, and learning theory proposes that parents model and reinforce gender stereotypes in their children (Bandura & Walters,

1977; Bussey & Bandura, 1999). For example, some research indicates that mothers talk more (Leaper, Anderson, & Sanders, 1998; MacDonald & Parke, 1984) and are more restrictive of physical risk-taking with daughters (Morrongiello & Hogg, 2004) than with sons. Other research indicates that western fathers and mothers are more elaborative in autobiographical storytelling with girls than boys (Fivush, 2011). Moreover, parents often encourage gender-stereotyped play behavior and household chores and discourage gender-atypical behavior (Lytton & Romney, 1991), and both mothers and fathers are more likely to engage in rough and tumble (RTP) play with boys than with girls (McIntyre & Edwards, 2009; Paquette & Dumont, 2013; Pellegrini & Smith, 1998). Related lines of research also point to differences in parental behavior related to child social and emotional development. For example, fathers of young children attend more to daughters' submissive emotional facial expressions (Chaplin, Cole, & Zahn-Waxler, 2005), convey gender stereotypes while discussing emotions with their children (van der Pol et al., 2015), and are more likely to express affection and respond to daughters' pro-social behavior (Hastings, McShane, Parker, & Ladha, 2007).

Despite the aforementioned research, there are considerable methodological challenges inherent to the study of gender socialization that limit confidence in previous findings. First, the social-

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ization of gender takes place in complex and multiply determined environments that do not lend well to testing mechanistic models (Eagly & Wood, 2013). Second, parents rarely self-report differential treatment of sons and daughters (e.g., Lytton & Romney, 1991), highlighting the importance of obtaining real-world observational measures (Fivush, 1998). Another challenge to the current research on gender differences in caregiving is that a majority of this research has been conducted on mothers, and it may be particularly important to examine gender differences in paternal behavior given research indicating that paternal gender socialization, compared with maternal socialization, may be disproportionately influential on child outcomes (Fitzgerald, 1977; Gottman, Katz, & Hooven, 1997; Grossmann et al., 2002; Power, 1981) and that fathers tend to more robustly differentiate between boys and girls (Lytton & Romney, 1991).

Systematic investigation of paternal caregiving may be particularly imperative given the role that socialization plays in child outcomes, particularly in the development of empathy and altruism. Since the earliest meta-analyses over three decades ago (Eisenberg & Lennon, 1983), a multitude of studies have reported on an apparent sex difference in empathy and its relevant components (Baron-Cohen et al., 2015; Christov-Moore et al., 2014; Hoffman, 1977; Moriguchi, Touroutoglou, Dickerson, & Barrett, 2014). Women in industrialized Western cultures are often found to have more interdependent concepts of self (Cross & Madson, 1997) and are more likely to have a nurturing response to psychosocial stress (Taylor et al., 2000). Although these data are often interpreted as biologically determined sex differences, they may also emerge from gendered socialization of emotion. Parental behavior is thought to influence the development of empathy and social intelligence. For example, a retrospective study found that adult empathy levels were related to paternal involvement in caregiving and maternal inhibition of aggression (Koestner, Franz, & Weinberger, 1990). Another found that maternal warmth and discipline style predicted peer-rated empathy of her child in adulthood, controlling for childhood levels of empathy (Eisenberg, VanSchyndel, & Hofer, 2015).

Examining gender differences in paternal behavior will be crucial for understanding gender socialization of empathy. Gender socialization appears to moderate the relationship between caregiving and child outcomes, and paternal impact may be particularly influential based in part on evidence that fathers may be more likely to invoke gender stereotyped norms than mothers (Fabes & Martin, 1991). Fathers of preschool children are more likely to engage in sex-typed socialization of empathy, with fathers of boys reporting less inclination to reinforce pro-social behavior and less affection toward their sons (Hastings et al., 2007). Fathers of young children in the Netherlands also exhibit more explicit gender stereotypes than mothers (Endendijk et al., 2013).

If parents differ in their behavioral responses toward sons and daughters, brain function should mediate these gendered differences. To date, several studies have examined the neurobiology supporting paternal caregiving. These data converge to suggest that paternal caregiving relies on brain systems similar to those involved in maternal caregiving, including the midbrain dopamine system for approach motivation [the ventral tegmental area (VTA) coupled with the substantia nigra (SN), the ventral striatum (VS), and the medial orbitofrontal cortex (mOFC)], along with cortical regions involved in mirror simulation, empathy, and mentalizing

(Feldman, 2015; Rilling, 2013; Rilling & Mascaro, 2017). However, to date no studies have examined the possibility that fathers' neural responses differ depending on whether they have a son or daughter, nor have any studies examined whether these gender differences relate to differences in behavior outside of the laboratory context. The present study set out to examine whether fathers' brains respond differently to daughters versus sons and whether these differences relate to gender differences in behavior.

To investigate the impact of child gender on paternal behavior and brain function in a sample of fathers with children aged 1–2 years, we first examined whether fathers of daughters were more attentive to their toddler, expressed more empathy, and used more affective expressions (laughing, singing, and complaining) and emotion language (angry, happy, sad) than did fathers of sons. We also investigated whether fathers of sons differed in their play activities (nonphysical play, RTP, and reading) compared with fathers of daughters. Second, we examined whether fathers of daughters have a greater neural response to their daughters' emotional facial expressions than fathers viewing their sons' emotional facial expressions. In particular, we were interested in neural responses in areas of the brain important for reward and for processing facial expressions of emotion, such as the ventral striatum, the OFC, the inferior frontal gyrus (IFG), and the anterior insula (AI; Feldman, 2015; Rilling & Young, 2014; Swain, Dayton, Kim, Tolman, & Volling, 2014). In an exploratory next step, we examined whether neural responses that differed by child gender were correlated with the behavioral variables that differed by child gender, and if so, whether brain activity mediated the impact of child gender on paternal behavior.

Method

Participants

As part of a larger study on paternal caregiving, we recruited 69 heterosexual, biological fathers of children age 1 or 2 who were currently cohabiting with the child's mother using flyers posted around the Emory campus, at local parks, daycare centers, and with an electronic advertisement on Facebook. The study was approved by the Emory Institutional Review Board, and all participants gave written informed consent. Participants had normal or corrected-to-normal (with contact lenses) vision and were screened and excluded for self-reported history of head trauma, seizures or other neurological disorder, psychiatric illness, alcoholism or any other substance abuse, serious medical illness, claustrophobia, and for ferrous metal in any part of body.

Fathers were between the age of 21 and 55 years ($M = 33.0$, $SD = 5.67$) and had between 1 and 4 children, with 2 as the modal number ($M = 1.79$, $SD = 0.74$; see Table 1 for descriptive statistics). Thirty-four of the fathers had a daughter and 35 of the fathers had a son. Fathers of daughters and sons did not differ in age, child age, ethnic composition, yearly combined household income, or hours worked per week.

Procedure

First, the mother completed self-report parenting questionnaires (results published elsewhere: Mascaro, Hackett, Gouzoules, Lori, & Rilling, 2014; Mascaro, Hackett, & Rilling, 2013, 2014) while

Table 1
Descriptive Statistics of Fathers of Daughters and Sons

Statistic	Girls' Mean (SD) (n = 30)	Boys' Mean (SD) (n = 22)	p
Child age	1.98 (.65)	1.93 (.59)	.74
Father age	33.0 (4.84)	33.0 (6.54)	1.00
Number of children	1.93 (.78)	1.64 (.66)	.16
Father ethnicity			.33
White	21	21	
Hispanic	4	1	
Black	5	8	
Asian	3	1	
Other or not reported	1	4	
Household income (year)	\$82,000 (53,000)	\$98,000 (53,000)	.26
Father hours worked (week)	38.2 (15.3)	39.9 (13.4)	.65

experimenters took naturalistic photographs of the child engaged in a play session. In a separate session, fathers were consented and given a mobile audio recording device, the Electronically Activated Recorder (EAR; Mehl, in press) that intermittently records ambient sounds around them (described below) and asked to wear the device on one weekend day (Sunday) and one weekday (Monday). In a third laboratory session, fathers completed self-report parenting questionnaires and provided saliva and blood samples, and were then positioned in the MRI scanner where they received structural and functional MRI scans of their brain.

Electronically Activated Recorder

Technically, the EAR is an audio recorder that intermittently records snippets of ambient sounds while participants go about their lives. Conceptually, it is a naturalistic observation method that yields an acoustic log of a person's day as it unfolds. The version of the EAR used in this study consisted of a Dell Axim X50 handheld computer with the EAR software programmed to record 50 seconds every 9 min. In reliability analyses, this sampling rate has yielded stable estimates of daily behaviors and robust effect estimates with criterion variables (Mehl, Robbins, & Deters, 2012).

We collected naturalistic observation data on fathers' real-world behavior toward their children from 55 fathers (25 boys, 30 girls), as 14 fathers experienced complete equipment failure (most frequent reasons were they forgot to charge it or the device was set incorrectly). Participants were excluded if they had fewer than 50 audio recordings during the 48-hour period ($n = 3$), so the final EAR data set contained 52 participants (22 boys, 30 girls). Fathers wore the EAR device in a protective case clipped to their waistline, with an Olympus ME-15 external microphone clipped to their lapels. The EAR was set to record between the hours of 8 a.m. Sunday and 8 a.m. on Tuesday and participants were asked to store and charge the device in their child's room at night. Participants had an average of 158.0 ($SD = 30.6$) valid (i.e., the father was wearing the device, and there were no technical problems), waking (i.e., the father was not sleeping) audio files that could be coded. For more information on the validity and ethical implications of the EAR method for studying parent-child interactions see (Alisic et al., 2015; Alisic, Barrett, Bowles, Conroy, & Mehl, 2016; Mehl et al., 2012; Slatcher & Robles, 2012).

A group of eight trained research assistants coded the audio files. All audio files were independently coded by two research assistants and, in all cases, one coder coded all of a participant's audio files. Coders were instructed to listen to each audio file at least twice and to use context information (from previous and consecutive sound files) to increase the accuracy of their codings. Captured words by the father were transcribed verbatim (with the first coder transcribing the words and the second coder cleaning the first coder's verbatim transcript). Coders were blind to the current research hypotheses. The data were collected in Atlanta, Georgia and the audio files were coded in Tucson, Arizona, minimizing any chances that the research assistants would know or recognize any of the participants.

A new coding system for extracting a range of social and emotional aspects of father-child interactions from the recorded ambient sounds was developed specifically for the purpose of this study. A full description of the development process is beyond the scope of this paper but will be reported elsewhere. In short, the new coding system was based on prior experiences with coding EAR recordings (Alisic et al., 2015; Mehl et al., 2012), other existing lab-based observational coding systems, and important information unique to this study (e.g., whether the participant was talking to his child, spouse, or a coworker). The coding categories included father affective expression (e.g., laughing, singing, complaining), toddler affective expression (e.g., laughing/giggling, fussing/crying), father-toddler activities (e.g., reading, nonphysical play, physical play), and paternal caregiving behaviors (e.g., engaged attending to the child, showing empathy or affection, expressing praise and encouragement). All codings were binary, reflecting the presence versus absence of a particular behavior in any given 50-s audio file. For fathers with more than one child, behaviors were coded as present only if they were directed toward the target child.

For the purpose of this study, interrater reliability for the variables of interest, computed as one-way random intraclass correlations for the average measure (ICC[1,2]), was: Singing: .87 ($M = 1.8\%$, $SD = 1.7\%$); Engaged Attending to the child: .86 ($M = 14.0\%$, $SD = 8.3\%$); Physical Play: .83 ($M = 0.4\%$, $SD = 0.7\%$); Showing Empathy: .35 ($M = 0.3\%$, $SD = 0.4\%$). The empathy variable was excluded from subsequent analyses due to its low interrater reliability. Variables were calculated with reference to the total number of (waking and compliant) audio files [$M(t)$], such that a $M(t)$ value of 1.0 indicates that 1% of all of the audio recordings contained that behavioral variable. We also report the percentage of the total number of audio files that included interactions with the child [$M(c)$], such that a $M(c)$ value of 1.0 indicates that 1% of the audio recordings where the father was interacting with the child contained that behavioral variable.

To analyze the language recorded by the EAR, we employed Linguistic Inquiry and Word Count (LIWC) (Pennebaker, Boyd, Jordan, & Blackburn, 2015), which is currently the most extensively validated word-count based text analysis tool in the social sciences. To derive information about fathers' language use when talking to their children, the overall verbatim transcripts were first separated by interaction partner. Information about whether the participant was talking to his child (and specifically, the target child), spouse, a coworker, or someone else was derived from the behavioral codings. The fathers' words spoken to their child, spouse, and coworker(s) were then submitted to three separate

LIWC analyses (in addition to a LIWC analysis of the fathers' overall word use). LIWC counts words by matching them to categories of dictionary words that represent specific domains, such as affect words (e.g., sadness), social words (e.g., family), core drives and needs (e.g., achievement), and biological processes (e.g., body). The variables based on these analyses are expressed as the percentages of all words spoken to the child, spouse, and coworker, respectively, in which a given LIWC category applied (e.g., percentage of all words the father spoke to the child that were sadness or anger words).

To address our first aim, we conducted independent sample t tests and calculated Cohen's d effect size values to examine whether behavior and language variables of interest differed between fathers of daughters and fathers of sons. For variables that violated normality assumptions, we used the standard SPSS adjustment of degrees of freedom using the Welch-Satterthwaite method. Behavioral variables of interest included engaged attending to the child (e.g., child is fussing and father responds), RTP (e.g., running, chasing, tickling, or swinging), and affectively laden interactions such as laughing, singing, and complaining. For the LIWC analysis, we were particularly interested in emotion language, such as that related to anger, sadness, and happiness. Given the exploratory nature of our analyses, we first used an alpha level of .05. Tests of the hypotheses were also conducted using Bonferroni adjusted alpha levels of .004 (.05/14). Statistics were performed on $M(t)$, but did not differ substantively when performed on $M(c)$.

Photograph Stimuli

As part of the larger study, fathers viewed photographs of an unknown adult, an unknown child, and their own child. A description of the methodology related to the unknown adult and child are found elsewhere (Mascaro, Hackett, Gouzoules, et al., 2014; Mascaro, Hackett, & Rilling, 2013; Mascaro et al., 2014). For the present study, we were interested in fathers' responses to their own child's face. We captured eight pictures of the father's child making each facial expression during a play session. If the child did not make one of the facial expressions naturally, sad faces were elicited by the mother leaving the room or taking a favorite toy or cell phone from the child, and happy faces were elicited with singing, dancing, or tickling. See supplementary Figure S1 for examples of each condition.

Anatomical Image Acquisition

Subjects were positioned in the Siemens Trio 3T MRI scanner. Subjects lay motionless in a supine position in the scanner with padded head restraint to minimize head movement during scanning. Each scanning session began with a 15-s scout, followed by a 5-min T1-weighted MPRAGE scan (TR = 2600 ms, TE = 3.02 ms, matrix = 256 × 256, FOV = 256 mm, slice thickness = 1.00 mm, gap = 0 mm).

fMRI Image Acquisition

Functional scans used an EPI sequence with the following parameters: TR = 2000 ms, TE = 28 ms, matrix = 64 × 64, FOV = 224 mm, slice thickness = 2.5 mm, gap thickness = 1.05

mm, 34 axial slices. TE was minimally decreased from the typical value (32 ms) to reduce magnetic susceptibility artifact in the orbitofrontal region. Subjects were imaged while viewing pictures of happy (H), sad (S), and neutral (N) facial expressions in three different people: (a) Their own child (O), (b) An unknown child (U), and (c) An unknown adult (A). Participants were instructed to "please observe each picture and try to share the emotions of the person in the picture." For each expression, fathers viewed 8 different pictures of the person making that expression over the course of 4 blocks, and each picture was viewed twice (see Figure S2). During a single block, 4 photographs of the same type were shown, each for 3 seconds. There was a 0.5 second fixation between each photograph. Thus the duration of each block was 14 seconds. After every 6 blocks, subjects viewed a fixation block of equal duration. The total duration of the task was 9 min 48 seconds (36 face blocks + 6 fixation blocks × 14 s per block). Photographs were presented in pseudorandom order, and fathers always viewed own children at the end so that their responses to unknown children could be compared to the responses from nonfathers in a related study.

Functional Image Analysis

Image preprocessing was conducted with Brain Voyager QX (version 2.0.8) software (Brain Innovation, Maastricht, The Netherlands). The first 8 volumes of each run were discarded to allow the tissue magnetization to equilibrate. Preprocessing involved image realignment by six-parameter 3-D motion correction, slice scan time correction using linear interpolation, spatial smoothing with a 8-mm full width at half maximum (FWHM) Gaussian kernel, and temporal smoothing with voxel-wise linear detrending and high-pass filtering of frequencies below three cycles per run length. Six subjects were excluded because of movement greater than 2 mm in the x , y , or z direction, so the final data set contained 59 participants. Images were subsequently normalized into Talairach space (Talairach & Tournoux, 1988).

A separate general linear model (GLM) was defined for each subject that examined the neural response to the following nine regressors: own child's happy face (OH), own child's sad face (OS), own child's neutral face (ON), unknown child's happy face (UH), unknown child's sad face (US), unknown child's neutral face (UN), unknown adult's happy face (AH), unknown adult's sad face (AS), and unknown adult's neutral face (AN). Because there was substantial attenuation of the BOLD response upon viewing each block repetition, only the first block of each condition was included in the GLM. Each regressor was convolved with a standardized model of the hemodynamic response. The resulting GLM was corrected for temporal autocorrelation using a first-order autoregressive model. For each subject, contrasts of parameter estimates for various predictors were computed at every voxel of the brain.

To address our second aim, we examined whether fathers of daughters responded differently to their child's happy, sad, or neutral facial expressions than fathers of sons. To this end, we conducted second level analyses using a standard analysis of variance (ANCOVA) in which sex of the child was entered as a between groups factor, which computes this effect separately for each voxel in a whole brain exploratory analysis. Results were thresholded at $p < .001$, and were corrected for multiple compar-

isons at the cluster level using Monte Carlo simulations as implemented by the Brain Voyager QX Cluster Threshold Estimator plugin. For the exploratory aim, we extracted beta contrast values from the regions identified in the ANCOVA and entered them in bivariate correlation analyses with the behavior and language variables identified as differing between fathers of sons and daughters.

Results

Behavior

The results of independent samples *t* tests comparing gender means in behavior and language as a percentage of all audio recordings are summarized in Table 2. Fathers of daughters engaged in significantly more singing or whistling with their child ($M(t) = 1.40\%$, $SD = 1.40$; $M(c) = 4.75\%$, $SD = 5.08$) than did fathers of sons ($M(t) = 0.30\%$, $SD = 0.50$; $M(c) = 0.96\%$, $SD = 1.36$), $t(38) = 3.69$, $p = .001$, $d = 1.05$ (Figure 1). Levene's test indicated unequal variances ($F = 7.80$, $p = .01$), so degrees of freedom were adjusted from 50 to 38. Differences in singing by fathers of daughters and son were significant at the Bonferroni adjusted alpha levels of .004. Fathers of sons engaged in significantly more RTP play ($M(t) = 0.70\%$, $SD = 0.90$; $M(c) = 3.20\%$, $SD = 4.21$) than did fathers of daughters ($M(t) = 0.20\%$, $SD = 0.40$; $M(c) = 0.90\%$, $SD = 1.38$), $t(26) = -2.48$, $p = .02$, $d = 0.72$. Levene's test indicated unequal variances ($F = 9.581$, $p = .003$), so degrees of freedom were adjusted from 50 to 26. Fathers of daughters attentively responded to their child ($M(t) = 16.1\%$, $SD = 8.20$; $M(c) = 54.5\%$, $SD = 18.1$) significantly more than fathers of sons ($M(t) = 10.8\%$, $SD = 7.40$; $M(c) = 42.6\%$, $SD = 20.6$), $t(50) = 2.40$, $p = .02$, $d = 0.68$.

When talking to their children, fathers of daughters also used more language related to sadness ($M = 0.45\%$, $SD = 0.72$) than fathers of sons ($M = 0.15\%$, $SD = 0.238$), $t(36) = 2.14$, $p = .04$, $d = 0.57$. Levene's test indicated unequal variances ($F = 4.085$, $p = .049$), so degrees of freedom were adjusted from 49 to 36. Fathers of daughters also used more language about the body ($M = 1.49\%$, $SD = 1.165$) than did fathers of sons ($M = 0.82\%$, $SD = 0.731$), $t(49) = 2.36$, $p = .02$, $d = 0.69$. Fathers of sons used significantly more achievement language ($M = 0.91\%$, $SD = 1.17$) than did fathers of daughters ($M = 0.33\%$, $SD = 0.41$),

$t(25) = -2.24$, $p = .03$, $d = 0.67$. Levene's test indicated unequal variances ($F = 13.68$, $p = .001$), so degrees of freedom were adjusted from 49 to 25. Fathers of daughters used more analytical language ($M = 36.9\%$, $SD = 19.3$) than did fathers of sons ($M = 27.2\%$, $SD = 13.5$), $t(49) = 2.015$, $p = .04$, $d = 0.58$. To examine whether gender of child impacted the language fathers used in other contexts, the same analyses were performed for fathers' use of sadness, body, achievement and analytical language in the context of coworkers and friends and there were no significant differences between fathers of daughters and fathers of sons. Results are summarized in Table 2.

Brain Activity

A whole brain exploratory analysis revealed that fathers of daughters respond more to their daughters' happy facial expression in areas of the brain important for visual processing (BA 17 and 18) and for reward, emotion regulation, and face processing, including medial OFC (mOFC) [BA 10, 11] and lateral OFC (lOFC) [BA 47] and left middle frontal gyrus [BA 10] compared with fathers of sons (Figure 2a).

Fathers of boys responded more robustly to their sons' neutral facial expressions in the thalamus, mOFC, and inferior temporal sulcus (Figure 3a). There were no significant differences between fathers of daughters and fathers of sons in the neural response to sad facial expressions. Results are summarized in Table 3.

Behavior–Brain Activity Associations

Regarding the extent to which behavior was related to neural responses, bivariate correlation analyses revealed that singing was positively correlated with activity in the right IOFC ($r(40) = 0.31$, $p = .05$; Fathers of boys (B): $r(16) = 0.34$, $p = .18$; Fathers of girls (G): $r(22) = 0.22$, $p = .30$; Figure 2b) and left frontal pole ($r(40) = 0.32$, $p = .04$; B: $r(16) = 0.49$, $p = .04$; G: $r(22) = 0.15$, $p = .48$). RTP was inversely correlated with neural responses to happy faces in the right IOFC ($r(40) = -0.40$, $p = .01$; B: $r(16) = -0.32$, $p = .19$; G: $r(22) = -0.53$, $p = .01$) and mOFC ($r(40) = -0.32$, $p = .04$; B: $r(16) = -0.34$, $p = .17$; G: $r(22) = -0.09$, $p = .68$; Figure 2c) and left IOFC ($r(40) = -0.32$, $p = .04$; B: $r(16) = -0.11$, $p = .66$; G: $r(22) = -0.47$, $p = .02$). Amount of analytical language was positively correlated with activity in the right IOFC ($r(39) = 0.32$, $p = .04$; B: $r(16) = 0.09$, $p = .74$; G: $r(21) = 0.35$, $p = .10$). Activity in the mOFC in response to neutral facial expressions was positively correlated with RTP ($r(40) = 0.36$, $p = .02$; B: $r(16) = 0.49$, $p = .04$; G: $r(22) = -0.21$, $p = .27$; Figure 3b); correlations are summarized in Table 4). In a final exploratory step, we examined whether brain activity mediated the impact of child gender on paternal behavior and did not find any significant mediation effects.

Table 2

Summary of Independent Samples *t* Tests Interrogating Differences in Behavior and Language Between Fathers of Daughters and Fathers of Sons

Behavior/Language	Girls' Mean (SD) (n = 30)	Boys' Mean (SD) (n = 22)	<i>t</i>	<i>p</i>
Rough and tumble play	.20% (.40)	.70% (.90)	-2.48	.02
Singing or whistling	1.40% (1.40)	.30% (.50)	3.69	.001*
Engaged responding	16.1% (8.20)	10.8% (7.40)	2.40	.02
Achievement	.32% (.41)	.91% (1.17)	-2.24	.03
Analytical thinking	36.9% (19.3)	27.2% (13.5)	2.02	.05
Body	1.49% (1.17)	.82% (.73)	2.36	.02
Sadness	.45% (.72)	.14% (.24)	2.14	.04

* Significant at the Bonferroni adjusted alpha level of .004 (.05/14).

Discussion

Previous studies indicate that the paternal brain responds to pictures of children's faces in much the same way as the maternal brain, specifically in neural systems important for reward and motivation (mOFC, VTA, and ventral striatum), emotion regulation (IOFC and dorsolateral PFC), and empathy (anterior insula and IFG; Feldman, 2015; Rilling, 2013; Rilling & Mascaró, 2017; Rilling & Young, 2014). The current project extends this work by

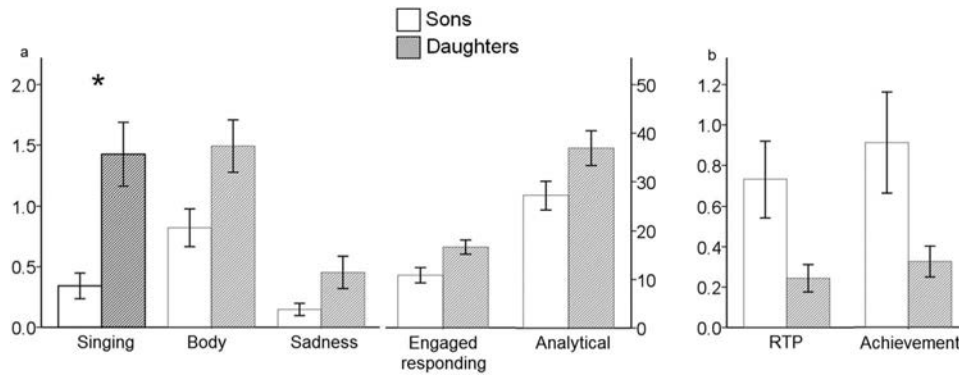


Figure 1. (a) Fathers of daughters sang more, used more language related to the body and to sadness, were more attentively engaged, and used more analytical language. (b) Fathers of sons engaged in more “rough and tumble play” and used more achievement language. All variables are represented as a percentage with reference to the total number of waking and compliant audio files. * indicates findings significant at the Bonferroni adjusted alpha level of .004. All other findings are significant at the alpha level of .05.

demonstrating that fathers’ brains respond differently to the emotional facial expressions of daughters compared with sons. Specifically, fathers of daughters had a more robust response to happy facial expressions in visual processing areas, likely reflecting increased attention of fathers to their daughters’ happy faces (Lane, Chua, & Dolan, 1999). Moreover, fathers of daughters exhibited a greater response in a region of the lateral OFC (BA 47) involved in emotion regulation, especially implicated in augmenting positive emotion (S. H. Kim & Hamann, 2007). Greater activity here may also be interpreted as an effect of increased attention. A recent meta-analysis indicated that lateral OFC (BA 10) and the inferior frontal gyrus orbitalis (BA 47) are often coactive during face processing tasks (Zald et al., 2014), providing support for the interpretation that fathers of daughters are attending to and processing happy facial expressions to a greater degree than

are fathers of sons. This difference was only significant for the response to happy faces, which is consistent with previous research showing that fathers attend more to daughters’ happy facial expressions (Chaplin et al., 2005) and are more likely to associate happiness with girls (van der Pol et al., 2015). We were surprised that fathers of daughters and sons did not differ in their response to sad facial expressions, but it is possible that the sad picture stimuli, many of which were of children actively crying, were so salient and evocative that they elicited a robust response in all fathers.

Fathers of daughters also had a more robust response to happy faces in the mOFC, a component of the mesolimbic dopamine system identified in diverse lines of research as important for parental responding (Feldman, 2015; Morten L. Kringelbach et al., 2008; Rilling, 2013). For example, our previous work comparing

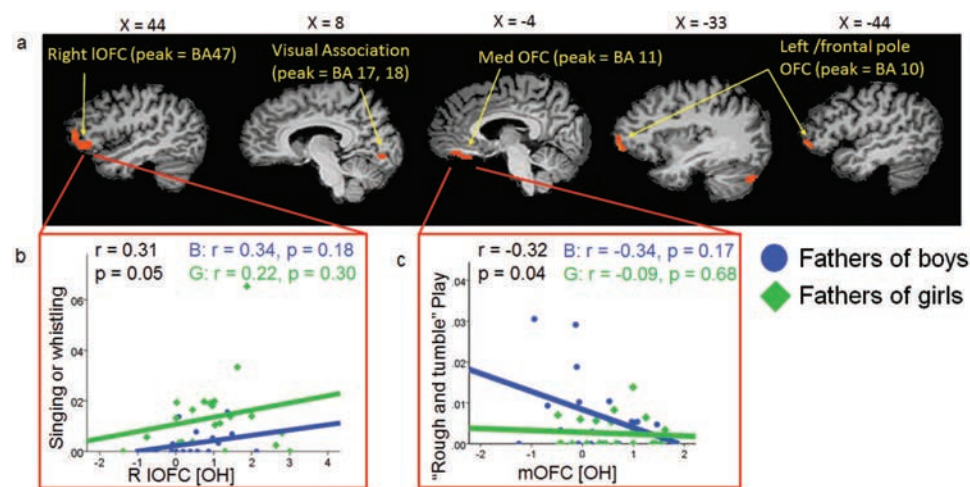


Figure 2. (a) Results of whole brain exploratory second level analysis indicating where fathers of daughters have more activity in response to their own child’s happy faces. All results are thresholded at $p < .001$, corrected for multiple comparisons using the Brain Voyager QX Cluster Threshold Estimator plugin. (b) Scatter plot of paternal behaviors and beta contrast values derived from the R IOFC and medial OFC ROIs, plotted as a function of group status. See the online article for the color version of this figure.

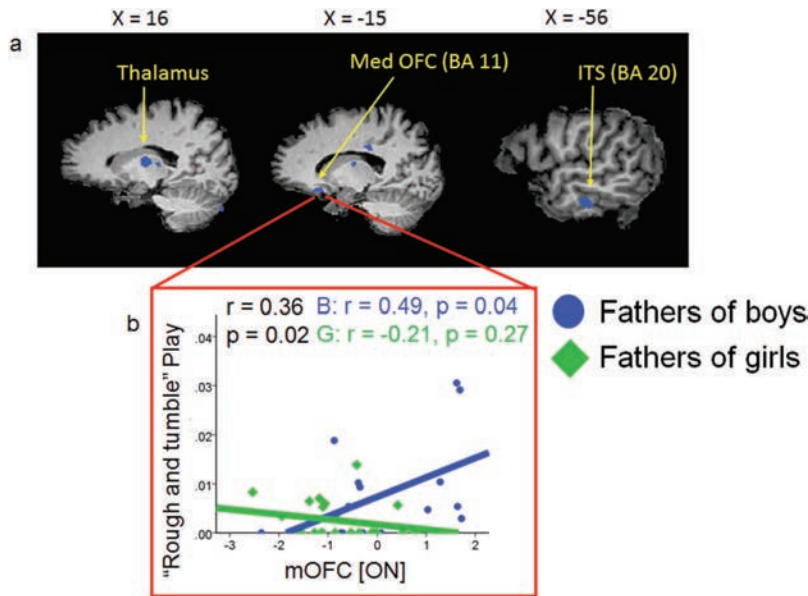


Figure 3. (a) Results of whole brain exploratory second level analysis indicating where fathers of sons have more activity in response to their own child’s neutral faces. All results are thresholded at $p < .001$, corrected for multiple comparisons using the Brain Voyager QX Cluster Threshold Estimator plugin. (b) Scatter plot of “Rough and tumble” play and beta contrast values derived from the med OFC ROI, plotted as a function of group status. See the online article for the color version of this figure.

fathers with age-matched nonfathers identified the mOFC as a region that was significantly more active in fathers in response to unknown child faces (Mascaro et al., 2014). This region may be integral for coding the hedonic pleasure associated with a stimulus (Kringelbach & Berridge, 2009), and intriguingly, it is this region that appears to respond early and selectively in response to infant faces (Kringelbach et al., 2008). Although speculative, this finding indicates that fathers of daughters may experience more pleasure when viewing their child’s happy faces than fathers of sons and future research can more definitively test this hypothesis by including pleasure ratings to query fathers’ reactions to their children’s happy faces.

It is interesting, then, that fathers of sons had a greater mOFC response to neutral facial expressions, and that this activity was

positively correlated with RTP. In fact, the correlation between mOFC activity and RTP was only significant for fathers of boys. Neutral faces should not to be misinterpreted as blank faces, devoid of meaning (Carvajal et al., 2013), and other lines of research indicate that neutral facial expressions may be more negatively or positively biased depending on context and characteristics of the perceiver (Demenescu, Kortekaas, den Boer, & Aleman, 2010; Leppänen, Milders, Bell, Terriere, & Hietanen, 2004). The fact that fathers of sons respond more robustly to neutral expressions renders it possible that these fathers are more strongly negatively or positively biasing neutral facial expressions of their sons. Future research may employ an affective bias task to examine the possibility that fathers of sons are more likely to attribute emotional valence to boys’ neutral facial expressions, and

Table 3

Results of Whole Brain Exploratory Second Level Analyses Using a Standard Analysis of Variance (ANCOVA) in Which Sex of the Child was Entered as a Between-Groups Factor for Own Happy [OH] and Own Neutral [ON]. Voxels are IMM Isotropic.

Variable	Brodmann’s area	x	y	z	Peak t	Voxels
OH ♀–OH ♂ (n = 59)						
R Inferior frontal gyrus (orbitalis), extending into middle frontal gyrus	47,46	51	31	0	5.12	2133
R Cerebellum		17	-74	-30	3.89	468
R Striate cortex	17,18	14	-89	-3	3.78	740
Rostral sulcus, extending into inferior rostral gyrus	11,10	0	37	-12	4.47	732
L Cerebellum		-31	-77	-30	4.35	840
L Middle frontal gyrus, extending into inferior rostral gyrus	10	-34	53	-3	5.04	1523
ON ♂–ON ♀ (n = 59)						
R Cerebellum		26	-80	-33	4.72	1038
R Thalamus		11	-14	12	4.49	4296
L Medial orbital gyrus	11	-13	22	-13	5.18	593
L Inferior temporal sulcus	20	-58	-29	-19	4.26	546

Table 4
Correlation Table of All Behavioral and Neural Variables

Variable	Right IOFC [OH]	MedOFC [OH]	Left frontal pole [OH]	Thalamus [ON]	MedOFC [ON]	RTP	Singing	Engaged responding	Achievement	Analytical thinking	Body	Sadness
Right IOFC [OH]		.43**	.79**	-.22	-.11	-.40**	.31*	.06	-.22	.32*	.05	-.19
Med OFC [OH]	.43**		.00	.17	.48	.01	.05	.69	.17	.04	.74	.22
Left frontal pole [OH]	.00	.47**		-.18	-.10	-.32*	.23	.01	-.08	.16	.04	.21
Thalamus [ON]	.79	.00	.00		.25	.04	.14	.94	.60	.31	.81	.18
MedOFC [ON]	.00	.47**	.08	-.27		.43	.04	.25	.05	.15	.51	.82
RTP	-.22	-.18	-.27	.11	.11		.06	-.13	.08	-.22	-.09	.08
Singing	.17	.25	.08	.47	.47	.71		.42	.62	.17	.59	.64
Engaged responding	-.11	-.10	-.12	.36*	.02	.06	-.14		.30	-.30	.00	.03
Achievement	.48	.51	.43	.47	.06	.36*	.06	.43	.06	.06	.98	.84
Analytical thinking	-.40**	-.32*	-.32*	.06	.36*	.02	.33	.71	-.03	-.20	.01	.10
Body	.01	.04	.04	.71	.02	.33	.71	.84	.15	.15	.97	.46
Sadness	.31*	.23	.32*	-.13	-.29	-.14	.46**	-.27	.18	.14	.45**	.08
Right IOFC [OH]	.05	.14	.04	.42	.06	.33	.00	.05	.12	.02	.00	.57
Med OFC [OH]	.06	.01	.18	-.19	-.13	.05	.46**	-.22	.14	.14	.25	.04
Left frontal pole [OH]	.69	.94	.25	.24	.43	.71	.00	.12	.33	.02	.08	.75
Thalamus [ON]	-.22	-.09	-.31*	.08	.30	-.03	-.27	-.22	-.33*	-.11	-.09	-.09
MedOFC [ON]	.17	.60	.05	.62	.06	.84	.05	.12	.02	.44	.52	.52
RTP	.32*	.16	.23	-.22	-.30	-.20	.18	.14	-.33*	.32*	-.24	-.24
Singing	.05	.31	.15	.17	.06	.15	.20	.33	.02	.02	.09	.09
Engaged responding	.05	.04	.11	-.09	.00	.01	.45**	.25	-.11	.32*	.01	.01
Achievement	.74	.81	.51	.60	.98	.97	.00	.08	.44	.02	.94	.94
Analytical thinking	-.19	.22	-.04	.08	.03	.10	.08	.04	-.09	-.24	.01	.01
Body	.23	.18	.82	.64	.84	.46	.57	.75	.52	.09	.94	.94

* Correlation is significant at the .05 level (2-tailed). ** Correlation is significant at the .01 level (2-tailed).

whether this has any bearing on their emotional interactions. A second possible interpretation of these data is that fathers of sons may find more reward in interactions that include ambiguous emotions, a characteristic of RTP. A longitudinal study found that new fathers experienced a decrease in gray matter in the mOFC that correlated with paternal intrusiveness during a play session (P. Kim et al., 2014). Although the decrease is surprising in light of research reviewed above highlighting the importance of the mOFC for parental responding, it is consistent with the idea that one role of the mOFC is to support the social ambiguity of RTP. It may be that fathers of sons employ more reward-related activity in response to neutral facial expressions, which then supports their engagement in RTP outside of the laboratory.

In addition to differences in neural responding, fathers of daughters and sons differed in behavioral and linguistic variables. The finding that fathers engage in more RTP with sons is consistent with a large body of prior research (Fletcher, StGeorge, & Freeman, 2013; Lewis, 1997; McIntyre & Edwards, 2009; Paquette & Dumont, 2013; Pellegrini & Smith, 1998). RTP involves dynamic and forceful behaviors, such as tickling, poking, and tumbling, which would be hostile in many circumstances and which can only be interpreted as play given the particular social context. For this reason, it is thought to both require and entrain emotion regulation and empathy. Research across many mammalian species attests to the importance of RTP for social competence and brain development (Bell, McCaffrey, Forgie, Kolb, & Pellis, 2009; MacDonald & Parke, 1984). In humans, paternal rough and tumble play is positively correlated with children's popularity with their peers (MacDonald & Parke, 1984).

Whereas fathers engaged in more RTP with sons, fathers of daughters engaged in more whistling and singing and were signif-

icantly more engaged and responsive to their daughters. The latter finding is germane to the research on gender socializations of empathy, suggesting that fathers of daughters are more present and attentive, as opposed to distracted, during interpersonal dyadic interactions. This may facilitate the development of increased empathy in girls. Unfortunately, while our more specific empathy variable also differed by gender, it proved difficult to code reliably from the recorded ambient sounds and future research may examine more precise real-world indicators of empathic parental behavior. Examining the behavioral findings as a whole, an intriguing hypothesis is that there are multiple routes for augmenting the development of empathy and emotion regulation, with fathers of daughters using more emotion language and greater attentional engagement to emotions, and fathers of sons engaging in more RTP. Future research can examine the possibility that fathers engage in differing approaches to foster emotion regulation, and can evaluate how children's emotional and social outcomes fare as a result.

Perhaps the most novel observation in these data were gender differences in linguistic patterns that were not predicted a priori. While fathers of sons use more language related to achievement (e.g., "top," "win," "proud"), fathers of daughters use more analytical language, which a previous study linked with future academic success (Pennebaker, Chung, Frazee, Lavergne, & Beaver, 2014). Previous research highlights the importance of paternal use of language with young children for shaping later verbal skills, even after controlling for other aspects of quality child care (Pancsofar & Vernon-Feagans, 2006). Taken together then, if the results hold in a future replication, the current findings suggest that gender differences in fathers' language may relate to future cognitive outcomes in meaningful ways and may help explain the consistent

finding that girls outperform boys in school achievement outcomes in countries committed to equal education opportunities (Epstein, 1998; Spinath, Eckert, & Steinmayr, 2014).

Additionally, fathers of daughters used more language referencing the body (e.g., “belly,” “foot,” “tummy”) relative to fathers of sons. This finding is relevant to research indicating that preadolescent girls are more likely to report body dissatisfaction (Wood, Becker, & Thompson, 1996) as well as more negative effects of body dissatisfaction on self-esteem (Furnham, Badmin, & Sneade, 2002). Other lines of research shows that body stigmatism begins in early childhood (e.g., (Cramer & Steinwert, 1998) and that parents exert an important influence on young children’s body image (Tatangelo, McCabe, Mellor, & Mealey, 2016). The EAR methodology may be useful for better understanding how parental language about the body influences child body image and whether the gender of the child moderates this link.

The finding that fathers of girls used more sadness language when talking to their child is consistent with previous studies in which parents report more acceptance of girls’ sadness (Birnbaum & Croll, 1984) and attend more to girls’ sadness and anxiety (Chaplin et al., 2005). This gender difference has real health consequences. Across diverse lines of research, restrictive emotionality in adult men is linked to marital dissatisfaction and depression (Shepard, 2002) and interferes with social intimacy (Sharpe & Heppner, 1991) and mental health help-seeking behavior (Robertson & Fitzgerald, 1992). Our findings using unobtrusive real-world observational assessments of language reveal that gender differences in emotion language begin early, in particular in the extent to which fathers use sadness language. We cannot determine the functional implications of this language difference, but future research can test the hypothesis that fathers’ reduced use of sadness language with sons impedes the socioemotional learning so integral for positive outcomes. Nor can we rule out the possibility that daughters somehow solicited sadness language more than sons, a real possibility given previous findings that very young girls use more emotion language than boys (e.g., (Cervantes & Callanan, 1998). An intriguing possibility is that there exists a positive feedback loop in which caregivers use more emotion language with girls, which then leads girls to use and solicit emotion language with their intimate caregivers.

The present study establishes a novel method for naturalistically observing and assessing meaningful parenting behaviors, and can be used in the future to more thoroughly investigate the biological bases of paternal and maternal caregiving. An important strength of the EAR methodology is that we can examine whether language variables directed at romantic partners or coworkers also differs as a function of the sex of the child. None of the language variables identified here as differing between fathers of daughters and fathers of sons differed in the coworker or friend context, allowing us to determine with confidence that gender differences in paternal language were specific to the domain of direct interactions with the child. Fathers had an average of 150 sound files, which equates to more than two hours of data spread over 2 days. Compared with a 15-min play session in a laboratory setting, the EAR allows for a more thorough evaluation of patterns of paternal involvement and the brain activity that support them. Moreover, as an unobtrusive observation method, the EAR is not beset with self-report biases, and may be particularly important for examining questions, such as

gendered behavior, often obfuscated by social desirability (Mehl, in press).

Although we have primarily interpreted these findings in the context of gender socialization, it is crucial to consider the possibility that gender differences in paternal behavior may be the result of fathers responding to differential cues from the children, some of which may be highly influenced by biological sex differences (e.g., hormone or neurobiological differences between male and female children). Males are exposed to higher levels of fetal testosterone, which plays an important role in brain organization, and there is literature causally linking fetal androgen exposure to rough and tumble play (Collaer & Hines, 1995; Pasterski et al., 2011). Not only does fetal androgen exposure influence play style, but there is some evidence that it influences playmate selection such that both boys and girls exposed to higher levels of fetal T are more likely to choose a playmate with a stereotypically masculine play style (Pasterski et al., 2011). Further support for the notion that fathers may alter their behavior in response to their toddler’s cues comes from a study indicating that fathers decrease their levels of physical play if their child is high on internalizing behavior (Jia, Kotila, & Schoppe-Sullivan, 2012). The authors interpreted their findings as reflecting fathers’ adaptation to children that respond negatively to play. In combination these findings lend support for the possibility that the male children of the fathers in our sample may “pull” RTP from fathers and highlights the important point that father-child interactions take place in a complex micro- and macro-environment (Cabrera, Fitzgerald, Bradley, & Roggman, 2014).

Other limitations warrant mention. First, this was an exploratory study with a relatively short EAR monitoring period. Although these data are far more comprehensive than a laboratory assessment, they were acquired over a period of two days (one weekend day and one weekday) and it is possible that for some fathers the study period was not accurately representative of their typical behaviors and interactions. Related, the EAR data are acoustic observations only, and as such visual cues were not available for behavioral coding. This may be particularly important with respect to our assessments of paternal affective behavior, and our assessment of empathy may have suffered from this limitation. In addition, this was a wide-ranging exploratory analysis and only the gender difference related to singing survived Bonferroni correction for multiple comparisons. Several of our findings were not predicted a priori and should be replicated in future research. Moreover, we were not able to detect any neural responses that significantly mediated the link between child gender and paternal behavior. Although paternal brain responses to the photograph stimuli were relatively robust, it may be that the neural response to the child’s dynamic behaviors in everyday life, more so than the neural response to still photographs of the child in the laboratory environment, mediates the relationship between child gender and paternal behavior. Finally, although the sample size provided sufficient statistical power to detect the gender differences in brain function, it is relatively small for studies examining parental behavior and was likely underpowered to detect mediation effects of brain function on behavior.

Despite inherent limitations, the present findings advance our understanding of the neural bases of paternal caregiving by uncovering neural systems that differentially respond to daughters versus sons and how those neural responses, in turn, may contribute to gendered paternal caregiving behaviors. Additionally, the use of the EAR revealed differences in paternal behavior and

language use that may relate to child social, emotional, and cognitive outcomes. Future research can employ this methodology for a more in-depth exploration of the impact of gender differences in paternal neural responses on child well-being.

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