

FATHER-CHILD INTERACTIONAL SYNCHRONY IN BRAZILIAN FAMILIES WITH MATERNAL DEPRESSION

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ABSTRACT

In this study we were primarily concerned with paternal behavior with a focus on its proximal (immediate causation) and distal (function and evolution) levels of analysis, in the context of maternal depression. Several authors point out the flexibility of paternal caretaking in nature and argue that, in humans, it is facultative and, thus, more open to calculations of maximizing inclusive fitness than maternal behavior (Hrdy, 2014; Storey & Walsh 2011; Storey, Delahunty, McKay, Walsh, & Wilhelm, 2006). In addition, evolutionary approaches of depression offer functional analyses highlighting its adaptive function (Hagen, 1999; Price, 1967). From an evolutionary perspective, postpartum depression can have a signal function communicating mother's need for extra support when she is unable to cope, especially from the partner (Hagen, 1999, 2002). Our main objective was to examine the associations between paternal behavior, maternal depression and family relationships. We hypothesized that when mothers are depressed, fathers assume a more active role within the family system, increasing investment to compensate for mother's "partial functioning" due to depression, promoting their child's well-being and, thus, potentially increasing their inclusive fitness. Forty-six father-child dyads were observed in a free-play situation and assessments of the degree of father-child interactional synchrony (interpersonal distance, visual and body orientation and dyadic involvement) were made. Greater father-child proximity and higher visual attunement, when mothers presented postpartum depression and later

depression were found. These results were discussed in relation to the evolutionary hypothesis of depression, Trivers' Parental Investment Theory and Family System Theory.

Keywords: *Father-child interaction, interactional synchrony, paternal investment, postpartum depression, depression, family system*

INTRODUCTION

Past studies suggest that maternal depression is a condition that can influence paternal behavior (Hagen, 1999, 2002; Paulson, Dauber, & Lieferman, 2006). Maternal depression is a highly prevalent condition, affecting millions of women worldwide, especially in the developing world (Silva, 2013). Several studies on the effects of maternal postpartum depression (PPD) on the child's development and well-being show its detrimental effects on the child and call attention to the need to examine it in conjugation with different factors (Field, 2010; Morais, Lucci, & Otta, 2013; Stanley, Murray, & Stein, 2004). In this study we are primarily concerned with paternal behavior with a focus on its proximal (immediate causation) and distal (function and evolution) levels of analysis, in the context of maternal depression. What happens to the family when mothers are less available for the child due to depression? Does the family collapse or, somehow, find a solution to overcome these difficulties? We will try to answer these questions by arguing that when mothers are depressed, fathers assume a more active role within the family system, increasing investment as a way to compensate mother's "partial functioning" due to depression and promote their child's well-being, and thus, increase their potential inclusive fitness. Moreover, we expect the relationship between paternal behavior and maternal depression be associated with the quality of family relationships.

Paternal behavior in the context of maternal depression

Paternal behavior in the context of maternal depression is still poorly understood. A hypothesis is that the partner may be a protective factor for the family by supporting the mother in many ways, including increasing paternal investment (Frizzo & Piccinini, 2007; Hossain, Field, Gonzalez, Malphurs, Del Valle, & Pickens, 1994). Some studies show that fathers are more positively involved in the social interaction with their children than their depressed partners, suggesting a more positive interactional pattern of fathers than mothers, when mothers are depressed (Hossain et al., 1994). Other studies show that father involvement with the child increases when the mother experiences PPD (Hops, Biglan, Sherman, Arthur, Friedman, & Osteen, 1987; Mendonça, Bussab, Rodrigues, Siqueira, & Cossette, 2013). A possibility is that partner's support, including an enhancement of positive interactions and involvement with their children, may activate maternal resilience mechanisms that would help the mother to deal with her depression.

Evolutionary approaches to depression highlight its adaptive function as an individual's protection mechanism and may help explain the increase of paternal investment when mothers are depressed (Hagen, 1999, 2002; Price, Sloman, Gradner, Gilbert, & Rohde, 1994; Spinelli, 2009). For example, Hagen (1999) proposes that PPD is a universal potential reaction to less favorable conditions, such as less viable seeming infant, mother less capable, or insufficient social support, which functions in part to protect the mother from wasting resources investing in the less viable infant, but also to avoid the social costs of insufficient caretaking, in the same way as depression at other times functions to reduce aggression whilst the individual slips down the social hierarchy (Price et al., 1994). In addition, suggests Hagen, depressive behavior is likely to elicit more social support, including - we both argue - increased paternal investment. Two important predictions derive from Hagen's hypothesis: on the one hand, women who perceive a lack of social support are at greater risk of developing PPD and, on the other hand, maternal PPD will enhance partner's support, including an increase in paternal investment. In this study, we suggest that maternal depression may indeed function as a call for help, in agreement to the second prediction. Hagen (2002) has also provided some empirical evidence showing that there is indeed an increase in paternal investment in the presence of PPD and Spinelli (2009) found that father's instrumental support was a protection factor for maternal PPD in a Brazilian sample.

In contrary, a decrease in paternal investment when mothers are depressed is also found in the literature. For example, Paulson, Dauber and Lieferman (2006) reported in a North American sample less involvement in men's parenting behaviors, such as reading to a child when mothers were depressed. In addition, Frizzo and Piccinini (2007), comparing father-child interaction in Brazilian families with and without depressed mothers found no significant differences in the interactive patterns. The inconsistency of these findings suggests the complex nature of the association between paternal behavior and maternal depression.

Evolution of paternal behavior

Paternal care is rare in most animal species. It occurs in less than 10% of all mammal species and it is present in humans (Kleiman & Malcolm, 1981). While human mothers are the main caretakers of their infants, Hrdy (1999) argues for the adaptive value of support to mothers from others (alloparenting), including from fathers. In addition, Trivers' theory of parental investment (1972) would predict an increase in paternal support for mothers, when maternal and other caretaking seems insufficient to meet the needs of the offspring. Consistent with fathers taking on caretaking roles, their hormonal responses show many parallels to the mothers: increases in oxytocin and prolactin levels and decline in testosterone (Hrdy, 2014). These changes towards the female pattern are associated with greater caretaking in fathers (Alvergne, Faurie, & Raymond, 2009).

Several factors have been found to influence paternal caretaking, such as age and mental health of father, sex and health of child, social support and cultural norms (Geary, 2000;

Keller & Chasiotis, 2007; Tokumaru, 2009). Storey and Walsh (2011) emphasize the flexibility of paternal caretaking and argue, like Hrdy (2014), that it is facultative and more open to calculations of maximizing inclusive fitness than maternal behavior (see also Storey, Delahunty, McKay, Walsh, & Wilhelm, 2006). The flexibility of paternal investment suggests that increased paternal support will not always be forthcoming, in consonance with the bimodality of Trivers' prediction (some fathers will increase investment but others will decrease). The challenge will be to elucidate the factors promoting paternal investment and the factors promoting disinvestment. The mixed findings of a number of studies reported above are consistent with this, and suggest a conjugation of factors influencing paternal investment. Nevertheless, we would expect to find an increase in paternal investment, at least under some conditions, when maternal caretaking is potentially compromised, as when the mother is depressed.

In addition, several studies from a systemic perspective (Minuchin, 1985) point out the important influence of the quality of the marital relationship on paternal behavior (Gray & Anderson, 2011; Parke, 1994). In this study, we argue that the relationship between paternal behavior and maternal depression may not be simple and nor is it a linear one. On the contrary, it may be better understood in conjunction with other factors, such as family relationships, in particular the interparental relationship. Therefore, we also expect to find an association between satisfaction in the marital relationship and increase in paternal investment, when the mother is depressed.

The Present Study

Our main objective was to examine the associations between paternal behavior, maternal depression and family relationships. To examine such a dynamical process, we have done a longitudinal study and an observation of a father-child free play interaction to assess the degree of father-child interactional synchrony. The specific objectives were: (1) to examine the effect of PPD continuing to 36 months of the child on paternal behavior at the child's 36th month of life; and (2) to examine the association between mothers' and fathers' perception of their interparental relationship and paternal behavior at the child's 36th month of life.

We hypothesized that paternal behavior would be associated with maternal depression and the quality of family relationships. More specifically, three hypotheses were proposed: (1) father-child interaction would be closer and more attuned when mothers presented postpartum depression and later depression compared to when mothers did not show PPD; (2) father-child interaction would be closer and more attuned if the parental relationship was more satisfactory; and (3) we expected mother's perception of father's involvement to correlate with observed father involvement.

METHODS

Participants

The present study was conducted in the context of a larger longitudinal research project at Universidade de São Paulo, Brazil, on the origins and consequences of postpartum depression in low-income families. The whole project was a four-year longitudinal study in which low-income mothers were followed from the third trimester of their pregnancy up to their child's third birthday. In total, seven meetings were held: third trimester of pregnancy, delivery and child's 3rd, 8th, 12th, 24th and 36th months. The participants were recruited in the university hospital and health centers from the same region of São Paulo. These medical centers are part of the public health system and are used mostly by a low-income population. The original sample included 400 mothers. Over the years, many participants could not be reached at previously reported addresses and telephone numbers, probably reflecting the precarious life conditions of most of them. They work in low-paying jobs and do not own a house. These life circumstances may lead to a more unstable lifestyle.

A subsample of sixty-eight mothers participated in the last meeting of the larger project. Fathers were invited to participate in this last visit at the child's thirty six months, and 46 fathers attended the interview. In total, 46 families participated in this specific study. Mothers were, on average, 26.3 years old ($SD = 5.6$; range = 16-43). Forty three percent of them ($N = 20$) had not finished secondary school, 43.5% ($N = 20$) had finished secondary school and 4.3% ($N = 2$) had completed higher education. At their child's 36th month, 52.5% ($N = 21$) of the mothers were employed and 91.3% ($N = 42$) reported being married or living with the father of the child. The majority of the children (65.2%, $N = 30$) were girls. All the mothers who answered the questionnaire about their socio-economic situation ($N = 40$) reported owning a color TV, 74% ($N = 30$) reported living in a house with a minimum of four rooms, 10% ($N = 4$) reported not owning a videocassette or DVD player, one woman reported not owning a fridge and 52.5% ($N = 21$) of them reported not having a car. Fathers were, on average, 29.5 years old ($SD = 6.9$; range = 18-48) at the birth of their child. Forty-two percent ($N = 19$) of the fathers had not finished secondary school, 44.4% ($N = 20$) had finished secondary school and 4.4% ($N = 2$) of them had completed higher education.

Measures

Data were collected on various aspects of mother's life and child's health and development, such as mother's social support, child's psycho-motor development, family interactions, blood and saliva measures for stress evaluation. Here we report measures relevant for this study.

The Edinburgh Postnatal Depression Scale (EPDS), (Cox, Holden, & Sagovsky, 1987).

The EPDS, validated in Brazil by Santos, Martins and Pasquali (1999), was used to indicate the occurrence of depression symptoms. The scale has also been validated for men

(Matthey, Barnett, Kavanagh, & Howie, 2001). It consists of 10 four-point self-report items (0 = never; 3 = always) (e.g., I have been capable of laughing and enjoying things; I have been feeling sad or very sad). Parents were asked to answer the questions based on how they felt in the past seven days. Cronbach alpha values were as follows -mothers at 3 months: .85, at 8 months: .82, at 36 months: .82, fathers at 36 months: .84.

Based on this measure, two groups, depressed and non-depressed, were created. The depressed group was composed of participants who had a score of 11 points or more on the scale. This cut-off point of 11 was suggested by Santos et al. (1999) in their validation study. A mother's profile scale variable was created considering the EPDS scores at 3, 8 and 36 months. Three groups of mothers were formed: 1. Never depressed (51%, N = 21); 2. Recovery of depression over time (10%, N = 4) mothers from this group were either depressed at 3 or 8 months, but not depressed at 36 months; 3. Severity of depression (39%, N = 16), mothers from this group presented symptoms of depression at 36 months and symptoms of previous depression at all moments or at least at 3 or 8 months. Five mothers from the 46 dyads included in this study were not included in the profiles because they did not have depression scores at all moments.

Father involvement, marital and co-parental relationship questionnaire (PATER).

This questionnaire was developed for this study and was adapted from Smith & Howard (2008) and Spanier (1976). It was conceived to measure parental perception of some aspects of family dynamics. It consists of 16 six-point self-report items on a scale from 0 to 5. It includes three dimensions: father involvement, co-parental relationship and marital relationship. The father involvement dimension consists of five items (e.g., question aimed to the mother: Does the child's father take the child to places like doctors and daycare centers?; question aimed to the father: Do you take the child to places like doctors and daycare centers?). The co-parental relationship dimension consists of two questions (e.g., question aimed to both parents: Do you and your partner agree on how to raise the child?). The marital relationship consists of nine questions (e.g., question aimed to both parents: Does your partner have time to talk when you need to? Do you feel very close to your partner?). This questionnaire was completed by the mother and the father at the child's 36th month. A score for each dimension was obtained by summing the items that constitutes each one of them. Cronbach alpha values for mother's perception of father involvement, co-parental relationship, and marital relationship were .50, .76 and .94 respectively. For father's perception, they were .57, .63 and .91, respectively.

Taxonomy of Interactional Synchrony, Mendonça et al. (2015), PsycTESTS database from the American Psychological Association.

This coding system scheme developed by the first author adopts a micro-analytic approach and it is based on nonverbal relational behaviors. The importance of non-verbal signals for communication is widely recognized (Argyle & Cook, 1976; Darwin, 1872; Eibl-Eibesfeldt, 1989; Hinde, 1972), and has been considered a good index of affective communication (De

Roten, Darwish, Stern, Fivaz-Depeursinge, & Corboz-Warnery, 1999). These observational measures provide a unique perspective on family interactions that cannot be captured by global constructs normally used in mother-child interaction studies (Mendonça, Cossette, Strayer, & Gravel, 2011).

Table 1. Taxonomy of Interactional Synchrony

Interpersonal Distance
1. More than 2 m
2. Between 1 and 2 m
3. Between 10 cm and 1 m
4. Less than 10 cm between the social partners
Visual orientation
1. The social partners look in different directions
2. Unilateral, child looks at parent or parent looks at child
3. The social partners look in the same direction
4. The social partners look at each other
Body orientation
1. The social partners face different directions
2. Unilateral, child faces parent or parent faces child
3. The social partners face the same direction
4. The social partners face each other
Dyadic involvement
1. No involvement
2. Unilateral behavior (initiation of gesture or talk with no response)
3. Joint attention (involving attention but no manipulation)
4. Joint activity (involving manipulation of the same object)

Table 1 presents the coding scheme. Measures include the social partners' interpersonal distance, visual and body orientation, and dyadic involvement. All categories are dyadic and capture the ongoing interaction between the social partners every 10 seconds. Each one of the categories of interactional synchrony is constituted by a four-point grading scale reflecting different "levels" of interactional synchrony with high numbers representing more interactional attunement. The coding of the video recordings was done using a time-sampling procedure; every 10 seconds, a code was noted, based on the last frame of the video, for the interpersonal distance, visual orientation and body orientation categories, and based on the full 10 seconds for the dyadic involvement category. In total, eight minutes of

social interaction were coded. To assess inter-observer reliability, 15 % of the dyads ($N = 7$) were coded by two independent observers after a training period. The data was coded by one of the observers after Kappa reached .70 for each category. The mean value of each category of the father-child interaction synchrony measures was calculated, and used for subsequent analysis.

Procedure

Mothers completed the depression instrument (EPDS) on three occasions (at the child's 3rd, 8th and 36th month) and the family relationships instrument (PATER) at the child's 36th month. At the child's 36th month, fathers completed the EPDS and the PATER and were observed in a free-play interaction with their children at the university laboratory during 10 minutes. Different types of toys were provided (e.g., dolls, balls, building blocks, etc.). The father was instructed to play freely with his child; no other instructions were provided. The situation was video recorded. Eight minutes of the social interaction were analysed. We started analysing the videos after two minutes of the beginning of the session, when the stress of both father and child was already smaller.

Mothers and fathers were interviewed separately. All questionnaires were applied orally by a female interviewer to ensure adequate understanding of the questions and to avoid the influence of the sex of the interviewer on the answers. All meetings occurred at the university laboratory. Participation in the study was on a volunteer basis. Transportation fees were paid and a snack was provided to the child at the end of the interview. A 10-session therapy was offered to the depressed mothers following the postpartum evaluation three months after the child's birthday. No mothers in our sample took part in this intervention program.

Analyses

Considering the longitudinal approach to maternal depression undertaken in this study, first we examined the association between mothers' PPD and mothers' later depression to understand if depression at one point in time was related to depression in the other moments, by using correlations analysis. Afterwards, we looked at the associations between father-child interactional synchrony and maternal depression (hypothesis 1). We conducted a series of partial correlations analyses controlling for paternal depression because previous analysis of our sample has shown that paternal depression increases fathers' proximity to the family (Mendonça et al., 2013). Then, we looked at the associations between father-child interactional synchrony and maternal and paternal perception of family relationships (hypothesis 2). We conducted another series of partial correlations analyses controlling for maternal depression, when looking for associations between maternal perception of family relationships and father-child interaction, because previous analysis has shown that maternal depression very negatively influences maternal perception of family relationships (Mendonça et al., 2013). Finally, to verify combined pathways of influence (using maternal depression and family relationship variables together) on father-child interaction, a series of

regression analyses were performed with the dimensions of father-child interaction measures (father-child interpersonal distance, visual orientation, body orientation and dyadic involvement) as outcome variables and a fixed set of predictors that were correlated to at least one dimension of father-child interaction as predictor variables.

RESULTS

Depression in mothers and fathers

The percentage of mothers showing signs of depression was 36% (N = 16) at three months, 29% (N = 12) at 8 months and 40% (N = 17) at the child's third birthday. At their child's third birthday, 29% (N = 13) of the men were also depressed. Table 2 shows the correlation among the depression scores for mothers and fathers. Mothers' depression scores were all correlated to each other. Fathers' depression scores at 36 months was positively correlated to mothers' depression scores at 36 months.

Table 2. Correlations between depression scores for mothers and fathers.

Depression Assessments	1	2	3	4
1. Mother: 3 months	1	.743**	.563**	.066
2. Mother: 8 months		1	.690**	.072
3. Mother: 36 months			1	.301*
4. Father: 36 months				1

Note: ***<.001; **<.01; *<.05

Father-child interaction as a function of maternal depression

Table 3 presents partial correlations of father-child interaction measures (interpersonal distance, visual orientation, body orientation and dyadic involvement) and mother's depression scores, controlling for father's depression. Results showed a positive significant correlation between father-child interpersonal distance and mother's depression profile ($r = .35, p = .03$) indicating that the more severe the maternal depression, the closer fathers are to their children during free play interaction, at the child's 36th month. Marginally significant results were also found for father-child visual orientation and mother's depression scores at 8 months ($r = .31, p = .05$), at 36 months ($r = .30, p = .05$) and mother's depression profile ($r = .30, p = .06$) suggesting a tendency of father-child higher visual attunement when mothers were depressed either at the child's 8th or 36th month and when they were severely depressed.

Table 3. Partial correlations results between father-child interaction dimensions and mother's depression

Father-Child Interaction (n=46)	Mother's depression (controlling for father's depression)			
	3 months (n=45)	8 months (n=41)	36 months (n=42)	Profile (3-8-36) (n=41)
Interpersonal Distance	.142	.113	.127	.345*
Visual Orientation	.144	.312*	.304+	.298+
Body Orientation	-.099	-.159	-.068	-.023
Dyadic Involvement	-.106	-.081	-.057	-.020

Note: ***<.001; **<.01; *<.05; + <.10

Father-child interaction as a function of parental perception of family relationships

Table 4 presents partial correlations of father-child interactional synchrony measures (interpersonal distance, visual orientation, body orientation and dyadic involvement) and mother's and father's perception of family relationships, controlling for mother's and father's depression, respectively at 36 months. Results from partial correlations analysis between maternal perception of family relationships and father-child interaction dimensions showed a positive significant correlation between mother's perception of father's involvement and father-child interpersonal distance ($r = .36, p = .02$) and father-child dyadic involvement ($r = .43, p = .005$) indicating that mother's positive perception of father involvement was associated with a shorter father-child interpersonal distance and a more attuned father-child dyadic involvement. Marginally significant results were also found for mother's perception of the marital relationship and father-child interpersonal distance ($r = .28, p = .07$) and father-child dyadic involvement ($r = .29, p = .07$) suggesting an association between mothers' positive perception of the marital relationship and father-child higher interactional attunement.

Results from partial correlations analysis between paternal perception of family relationships and father-child interaction dimensions showed a positive significant correlation between father's perception of the marital relationship and father-child body orientation ($r = .40, p = .01$) indicating that father's positive perception of the marital relationship was associated with more attunement in father-child body orientation.

Father-child interaction as a function of maternal depression and parental perception of family relationships together

A series of linear multiple regression analyses were performed with 3 dimensions of father-child interaction measures (father-child interpersonal distance, visual orientation and dyadic

involvement) as the outcome variables and a fixed set of predictors that were correlated to father-child interaction on at least a marginally significant degree, as predictor variables. The body orientation dimension was excluded from this analysis because it did not correlate with any of the predictors. Table 5 presents the three models that were tested. In model 1, mother's depression profile and mother's perception of the marital relationship together accounted for 29% of the total variance on father-child interpersonal distance. Mother's depression profile was the strongest predictor ($Beta = .64, p < .001$) followed by mother's perception of the marital relationship ($Beta = .47, p = .004$). These results indicate that the more severe maternal depression, the closer the interpersonal distance between the child and the father was at the child's 36th month. It also indicates that the more the mother perceived her marital relationship as positive, the closer father-child interpersonal distance got. In model 2, mother's depression profile accounted for 9% of the total variance on father-child visual orientation ($Beta = .33, p = .034$). These results indicated that as mother's depression got more severe, more visual attunement between the child and the father occurred at the child's 36th month.

In model 3, mother's perception of father's involvement accounted for 16% of the total variance on father-child dyadic involvement ($Beta = .43; p = .006$) indicating that a positive maternal perception of father's involvement was associated with observed paternal involvement in father-child interaction.

Table 4. Partial correlations results between father-child interaction dimensions and mother's and father's perception of family relationships

Father - Child Interaction (n=46)	Mother's perception (controlling for mother's depression at 36m)			Father's perception (controlling for father's depression at 36m)		
	Father involvement (n=46)	Marital relation (n=46)	Coparental relation (n=46)	Father involvement (n=46)	Marital relation (n=38)	Coparental relation (n=46)
Interpersonal Distance	.359*	.285+	.111	.119	.193	.091
Visual Orientation	.121	.082	-.140	-.258	-.028	-.215
Body Orientation	.082	.176	.186	-.059	.399*	.131
Dyadic Involvement	.432**	.286+	.067	-.017	.217	-.074

Note: ***<.001; **<.01; *<.05; + <.10

Table 5. Multiple regression models predicting father-child interactional synchrony at the child's 36th month

	Model 1	Model 2	Model 3
	Father-child interpersonal distance R² = .291	Father-child visual orientation R² = .090	Father-child dyadic involvement R² = .160
Predictor variables	Beta	Beta	Beta
Mother's depression profile	.635**	.333*	.103
Mother's perception of father Involvement	.165	0.69	.425**
Mother's perception of marital relationship	.466*	0.80	-.010

Note: ***<.001; **<.01; *<.05; + <.10

DISCUSSION

The main objective of this study was to examine the associations between paternal behavior, maternal depression and family relationships. The high percentage of depression at all periods among mothers and at the child's 36 months among fathers is noteworthy. The percentage of mothers with depression symptoms at 3 months was 36%, at 8 months it was 29% and it was even higher at 36 months, reaching 40% of the total sample. Twenty-nine percent of fathers reported symptoms of depression at the child's 36th month. Although seemingly high, these findings are similar to the percentages reported in other studies conducted in similarly adverse social contexts (Silva, 2013). Our sample is from an urban low-income social class which faces a stressful daily routine in a developing metropolis of 19 million people, with precarious public services. Most likely, these difficult life conditions have an impact on their mental health and well-being in general. According to data from the *World Health Organization*, more than 350 million people are estimated to suffer from depression (WHO, 2012). It is very present in developing countries, especially among women, within a vicious cycle of poverty and depression (Abas & Broadhead, 1994). Positive correlations were found between maternal depression assessments at 3, 8 and 36 months replicating the recurrent pattern of depression reported in the literature (Lee, Yip, Leung, & Chung, 2000).

Consistent with our hypothesis, maternal depression accounted for some of the father-child interaction total variance. Severity of maternal depression was associated with closer father-child interpersonal distance and more father-child visual attunement at the child's 36th month. Also, when mothers were depressed at the child's 8 and 36 months, fathers and

children showed more visual attunement at 36 months. These results provide evidence of fathers' compensating for maternal difficulties (due to depression) by increased paternal investment, as predicted.

There was no association between father-child interaction and maternal depression at the child's third month, the usual peak of mothers' PPD symptomatology. A plausible explanation is that fathers only increase their investment in the child at a later stage of the child's development, when the child's contribution to the interaction increases and the lack of mother's responsiveness to the child's initiatives, typically found in depressed mothers, may become more obvious to the father. Around 9 months, the child becomes a more active social partner, contributing more intensively to the dyadic interaction (Hedembro, 2006; Tomasello, 2008). This interpretation predicts that maternal depression would affect father-child interaction at 8 and 36 months, but not at 3 months. We cannot test this hypothesis because we only have data on father-child interaction at the child's 36th month. Future studies should also address this hypothesis of greater paternal investment as the child becomes a more active social partner. Although no direct effect was observed, an indirect effect was found considering that maternal depression at 3 months was highly correlated to maternal depression at 8 and 36 months. The data indicates that as maternal depression goes on and mothers do not overcome it, paternal investment increases.

We can interpret our results from the perspective of Trivers' theory of paternal investment (1972) and Hagen's functional hypothesis of PPD (1999). Trivers proposed that expression of paternal behavior can be understood as a trade-off between costs and benefits. Men have the potential to care but they will only express paternal behavior if the benefits (promoting the child's well-being and future competitiveness) surpass the costs of caring and losing mating opportunities. In this case, Trivers might suggest that these fathers subconsciously "calculate" that enhanced investment would increase their inclusive fitness. However, there will be other times when fathers "calculate" that it is best for their inclusive fitness to reduce investment, perhaps to zero. In the case of maternal post-partum depression, an increase in paternal investment may be essential to promote the child's well-being. Furthermore, these results also support Hagen's functional analysis of PPD as a maternal bargain strategy to gain support and the prediction of increase in paternal investment when mothers have PPD.

Mothers' and fathers' perception of their marital relationship also accounted for some of the variation in father-child interaction. Mothers' positive perception of the marital relationship was associated with a closer father-child interpersonal distance. On the other hand, fathers' own positive perception of his marital relationship was associated with more body attunement in his interaction with the child. These results replicate past studies showing that the way fathers and children interact is partially influenced by their own perception of their marital relationship (Gray & Anderson, 2010; Parke, 1994) and extends them by showing that it is also influenced by how their partners (mothers) perceive their marital relationship. Our results show the interdependence among family members and the influences on one another, especially from the mother on father-child interaction, and

suggest that the relationship between mother's depression and father's paternal behavior within the family system is, in a complex way, mediated by the quality of husband-wife relationship, as it is perceived by both parents, which is in line with the family systems theory. Family System Theory was initially proposed by Minuchin (1985) and is based on Bronfenbrenner's (1986) family ecology ideas. It examines the complex network of interacting relationships within families (see also, Belsky, 1999; Fivaz-Depeursinge & Corboz-Warnery, 1999; Mendonca, Cossette, Lapointe, & Strayer, 2008). Moreover, considering the multiplicity of the possible environmental influences on the expression of paternal behavior, the effect size of 29% obtained, combining maternal depression and mothers' perception of their marital relationship, explaining the total variance of father-child interpersonal distance represents a quite powerful effect.

This study demonstrates the complex negotiation between spouses, mediated by the emotions elicited by depression, during the collaborative venture of caring for offspring, in which cooperation and conflict coexist. Because in most contemporary societies paternal care is not essential for offspring survival (Hyrd, 2014), the bargaining between parents is likely to be intense. In Trivers' words "...even when ostensibly cooperating in a joint task, male and female interests are rarely identical" (1972, p. 174). In the context of a cooperative venture, such as caring for offspring, maternal depression may also be understood as a trade-off between costs and benefits. Mothers suffering high costs (caring for offspring with little help) will reduce the benefits to the partner (by not caring appropriately for offspring and affecting partner's inclusive fitness) until more benefits are forthcoming (fathers increasing paternal investment). However, in a previous multivariate analysis we found a significant effect of mother's high social support and high education but not of marital conflict on maternal PPD (Mendonça, Bussab, Siqueira, & Lucci, 2013b), suggesting that other factors, and not the partner especially, may also work as emotional support for the mother. It is possible that the negative effects of marital conflict on maternal PPD are attenuated in the presence of other kinds of social support (other members of the family and friends) that may function as a safety net for the mother. In this case, the mother can expect increase in support from her wider social network and not only from the partner, in a situation of depression. Future studies should also include measures of other kinds of maternal support.

A limitation of this study is that the results may be hard to generalize to Brazilian fathers because our sample was constituted by partners of low-income mothers attending the public health system in a specific region of São Paulo. These mothers were participating in a larger project on maternal PPD, and were being followed since pregnancy. Many of the mothers dropped out over the years, and it is possible that the ones who continued participating in the project and the fathers who attended the invitation to participate in this study were biased towards more participation in the family, representing an extreme of the bimodality of investment. This possibility may explain why the bimodality of paternal investment (increased support by some fathers but decreased by others) was not seen. Also, we have not controlled for paternity, neither perception of paternity certainty of the involved fathers,

which is a relevant factor in studying paternal behavior, and should be taken into account by future studies.

To conclude, the proximal analysis undertaken in this study benefited from and corroborated evolutionary hypotheses of human behavior and psychological functioning. We also would like to reinforce the need to involve the partner in prevention programs and treatment of depression, and to emphasize the importance of providing support to depressed mothers.

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