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Running Head: FAMILY INTERACTIONS

Observed sensitivity during family interactions and cumulative risk: A study of multiple dyads per family

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Abstract

The present study sought to investigate the family, individual and dyad-specific contributions to observed cognitive sensitivity during family interactions. Moreover, the influence of cumulative risk on sensitivity at the aforementioned levels of the family was examined. Mothers and two children per family were observed interacting in a round robin design (i.e. mother-older sibling, mother younger-sibling and sibling-dyad, N=385 families). Data were dyadic, in that there were two directional scores per interaction, and were analyzed using a multilevel formulation of the Social Relations Model. Variance partitioning revealed that cognitive sensitivity is simultaneously a function of families, individuals and dyads, though the importance of these components varies across family roles. Cognitive sensitivity for mothers was primarily attributable to individual differences, while cognitive sensitivity for children was predominantly attributable to family and dyadic differences, especially for youngest children. Cumulative risk explained family and individual variance in cognitive sensitivity, particularly when actors were older or in a position of relative competence or authority (i.e. mother to children, older to younger siblings). Overall, this study demonstrates that cognitive sensitivity operates across levels of family organization, and is negatively impacted by psychosocial risk.

Keywords: sensitivity; cumulative risk; social relations model; family

Observed sensitivity during family interactions and cumulative risk:

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According to family systems theory, the family-unit is an emergent and dynamic entity characterized by complexity in terms of function *and* structure (Carr, 2012). In spite of the prolific history of family systems theory and family therapy practice, there is a relative paucity of empirical literature that conceptualizes family functioning using these systemic organizing principles (Eichelsheim, Dekovi , Buist, & Cook, 2009). In the present study, we employ a methodology that can differentiate between sources of influence in families, and determine whether interactional behaviors are mainly attributable to individuals, particular dyadic combinations, or whole families. Specifically, we consider this issue with respect to *observed sensitivity* – the interactional behavior which best predicts social and emotional outcomes in infancy and early childhood (e.g. Belsky & Fearon, 2002). Currently, there is a growing emphasis on the cognitive (versus affective) components of sensitivity. Indeed, sensitivity to the cognitive states of others is a critical developmental influence and skill. However, we do not understand the contextual influences on sensitivity within dyads or through the family context.

Observed Sensitivity during Family Interactions

The vast majority of research on interpersonal sensitivity in early life has focused on mothers. Maternal sensitivity has been linked to emotion and anger regulation (Feldman, Dollberg, & Nadam, 2011), joint attention and attentional control (Belsky, Pasco Fearon, & Bell, 2007), infant communication (Gunning et al., 2004), cognitive development (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012), adrenocortical responses and other physiological indicators (Feldman, 2006), compliance (Feldman & Klein, 2003), and attachment security (NICHD, 2001). Maternal sensitivity is higher across *all* children in households when mothers are positively adjusted and when families are living in less risky environments (Atzaba-Poria & Pike, 2008; Browne, Meunier, O'Connor, & Jenkins, 2012).

Historically, the majority of research on maternal sensitivity has focused on contingent responding to infant affective signals (Sroufe, 2005). A more recent line of research has emphasized maternal sensitivity towards a child's cognitive states (Landry, Smith, Swank, & Guttentag, 2008; Meins et al., 2002). Prime and colleagues (2015) have developed a construct called *cognitive sensitivity (CS),* describing "the extent to which a mother [contingently] responds to her child's inferred cognitions" (p. 489). This phenomenon can be readily assessed when dyads are engaged in challenging tasks. A tripartite model of CS has been demonstrated, comprised of *mutuality building* (i.e. reciprocal interactions characterized by turn-taking and a positive valence), *mind reading* (i.e. consideration of a child's understanding and adjustment of responses to a child's specific needs), and *communicative clarity* (i.e. the provision of non-ambiguous verbal and non-verbal guidance to promote awareness surrounding task demands). Maternal CS is lower in the presence of risk (e.g. maternal abuse history and depression, large family size), is predictive of child outcomes (e.g. theory of mind, executive functioning and psychopathology), and mediates the relationship between risk (e.g. low socioeconomic status) and later cognition (e.g. receptive vocabulary; Prime et al, 2015).

The construct of sibling sensitivity has only recently been developed, though similarly explains developmental outcomes. For example, Prime and colleagues (2014) have developed a complementary coding paradigm for CS during sibling interactions, with similar psychometric properties including predictive and convergent validity. Other studies have demonstrated that the presence of siblings promotes cognitive and psychosocial development in theory of mind, false belief understanding, communicative abilities and social skills (McAlister & Peterson, 2007).

Indeed, cooperative sibling interactions are linked to enhanced social abilities (Hughes, Fujisawa, Ensor, Lecce, & Marfleet, 2006). Given the importance of maternal *and* sibling CS, it becomes critical to understand contextual (whole family or dyadic) and individual influences in its development, as well as variations as a function of developmental stage and family role.

It is important to articulate why CS is expected to be a key component of family life. First, Prime and colleagues (2015) demonstrated that there is significant overlap between CS, standard measures of observed maternal *affective* sensitivity, and outcomes in early childhood. Secondly, the CS construct has been developed alongside advancements in developmental neuroscience. Specifically, it is becoming increasingly clear that highly attuned and reciprocal social interactions operate as intersubjective precursors to the development of autonomous cognitive abilities (Blair & Raver, 2012) – a phenomenon occurring across multiple dyads within the family (Prime et al, 2014; 2015). Finally, the present emphasis on CS *does not* discount the importance of traditional constructs, including warmth/positivity and conflict/negativity. As such, we sought to employ a construct (and corresponding measurement) that emphasized the attunement to the mental states of other family members during real time interactions.

Isolating the Importance of Families, Individuals, and Dyads using the SRM

Before proceeding, it is critical to describe how the social relations model (SRM) isolates variability in CS across families, individuals, and dyads (Kenny, Kashy, & Cook, 2006). Of note, it is required that family members interact with one another in a pair, and are each rated for the sensitivity that the person directs towards their partner (i.e. dyadic data). Subsequently, family, individual, and dyadic-specific effects are contrasted in terms of magnitude. First, a *family effect* is isolated, referring to the average amount of CS in a given household. This estimate quantifies the extent to which sensitivity is operative as an ambient household climate. Second, individuals are distinguished by 'role' (e.g. mother, older sibling, younger sibling) and separate 'actor' and 'partner' effects are identified. The *actor effect,* measures the average amount of CS a particular individual directs towards others, while the *partner effect* measures the average amount of CS an individual receives from others. Third, after isolating family and individual effects, it becomes possible to identify a *dyad effect,* or the level of sensitivity a family member exhibits towards another after accounting for the family, actor and partner effects. The relative importance of family, individual (actor and partner) and dyad effects on CS are summarized by their variance components. For example, proportionally larger family variances would suggest that CS is predominantly a function of families (i.e. some families tend to be more sensitive than other families). These proportional variances are permitted to vary by family role.

There are two other parameters that identify reciprocity of family members at the individual and dyad-specific levels of analysis. *Generalized reciprocity* or the *actor-partner correlation* represents the general correspondence between CS individuals "give off" and "get back" across all relationships. For example, mothers who exhibit more sensitivity compared to other mothers, on average, may receive more CS from their children in return (i.e., positive generalized reciprocity). The *dyadic reciprocity correlation* indicates correspondence between the CS that two family members show each other. For example, it is possible for a mother to show more sensitivity to one particular child, and for this child to respond to the mother accordingly, relative to the average for those individuals (i.e., positive dyadic reciprocity).

Given that there are no SRM studies of sensitivity, *per se*, in early childhood, hypotheses regarding the importance of families, individuals and dyads are somewhat difficult to make. There is one observational SRM in early childhood (mother, father, two children), where six domains of play were explored across interactions (N=32, younger child = 1 year, older child =

3-4 years; Stevenson, Leavitt, Thompson, & Roach, 1988). From this study, authors concluded that dyadic variance components were most important for children and parents. There were some very small but significant individual (actor/partner) components for children depending on the domain of play. Notably, the Stevenson et al. (1988) study constrained estimates to equality for older and younger children and did not estimate a global family variance.

Existing self-report and observational SRM studies of adolescent youth also provide guidelines surrounding the expected variance partitioning. Eichelsheim et al.'s (2009) systematic review of self-report SRM's indicates that family differences account for 8% to 18% of the variability in ratings, suggesting modest but important consistency in relational processes within families. For individual differences, 34% to 47% of the variability is attributable to what individuals typically direct towards others (i.e. actor variance), while 12% to 18% concerns what individuals typically receive (i.e. partner variance). This suggests that, after accounting for family differences, individuals play an important role driving interactions, although this is greater for what individuals direct towards others rather than what they receive. Notably, results from the Eichelsheim et al. (2009) review imply that children have *larger* actor variances than parents. This is because (1) many of these investigations included both mothers *and* fathers, (2) child actor variances reflect consistency across partners, and (3) children often make similar attributions across parents. As discussed below, the exclusion of fathers and focus on observed CS in the current study may yield differing results. Furthermore, small partner effects are expected for all family roles, as relationships are more nuanced (i.e. dyadic) amongst highly acquainted individuals (as in the case of families).

After accounting for family and individual differences, Eichelsheim et al. (2009) report that 26% to 32% of the variability in ratings occurs across dyads. In other words, there is a large amount of variability that is attributable to the unique components of a particular relationship, irrespective of family and individual differences. In terms of reciprocity correlations, the review reported “no clear pattern” in terms of generalized reciprocity, often due to the presence of non-significant partner variances. However, dyadic reciprocities tend to be positive and significant.

Two observational studies of adolescents yielded findings similar to self-report investigations (Ackerman, Kashy, Donnellan, & Conger, 2011; Rasbash, Jenkins, O'Connor, Tackett, & Reiss, 2011). While not the focal age group in the current investigation, these studies are still informative to our hypotheses. Ackerman and colleagues (2011) conducted an SRM on a sample of families (mothers, fathers & two children), where younger and older children were 11 and 13 years old, respectively (N≈400). This study examined family positive engagement, defined as “an interpersonal style characterized by attentiveness, warmth, cooperation, and clear communication (p. 1).” In a similar four-person SRM, Rasbash and colleagues (2011) examined positivity during family interactions defined as warmth, assertiveness, communication, involvement, and self-disclosure. Siblings were between 10 and 18 years of age (N≈700). Both studies identified significant family variance (16% to 24%), and actor variance for mother and child family roles (27% to 33% for younger siblings, 20% to 55% for older siblings, and 28% to 38% for mothers). These findings may imply similar family and individual components in CS for mothers *and their young children*. However, Rasbash et al. (2011) compared variances across roles, finding some evidence for larger maternal versus child variances for positivity (but not negativity). Furthermore, is possible that the unique developmental context of the present investigation would augment these differential findings as a function of family role.

Development of an Autonomous Cognitive Sensitivity

Early child behavior is heavily guided by interpersonal influences in the proximal social environment (Sameroff, 2010). Complementary to CS, this phenomenon has been described under the frameworks of mother-child synchrony (Feldman, 2006), mutually responsive orientation (Kochanska & Aksan, 2004), and transactional co-regulation (Sameroff, 2010). These models globally attest that children's sensitive responding is inextricably tied to that of others. There is a developmental shift in sensitivity across childhood, whereby parents play a larger role driving interactions in early life due to asymmetry in terms of parental versus child competence (Kochanska & Aksan, 2004). Furthermore, it appears that sensitive interactions are keystone experiences that provide children with the opportunity to internalize an autonomous social skill-set, contributing to the development of individual agency and various cognitive and socio-emotional abilities (Blair & Raver, 2012). In part, this occurs when parents lead children through challenging interactions that are beyond their developmental level (Fernyhough, 2008).

In SRM nomenclature, the aforementioned findings imply that the CS of young children would be more attributable to the environment (i.e. family and dyad), versus the individual (i.e. child actor variance). Conversely, the sensitivity of mothers would be primarily attributable to actor differences, consistent with the primacy of shared influences on maternal sensitivity towards twins (O'Connor & Croft, 2001). This hypothesized patterning is further supported by normative theory of mind development and children's emerging abilities to consider the mental states of others around 3 to 4 years of age. Specifically, the emergence of theory of mind occurs as children engage with cognitively sophisticated partners who facilitate, guide, and scaffold the development of shared social understanding (Fernyhough, 2008). Over time, there is a systematic reallocation of the variability in self- versus other-regulation during interactions, as these co-activated interpersonal processes become increasingly represented within individual cognition

(Clancy & Raver, 2012; Sameroff, 2010). Accordingly, CS would become a characteristic of the individual (i.e. actor) versus the context (i.e. the family and dyad) as children become increasingly self-directed, self-organizing, and agentic. Thus, it was hypothesized that the actor variance in CS would be larger for older versus younger siblings, though still not as large as actor variance for mothers. To date, the absence of a SRM investigation of CS in early life has precluded the direct empirical testing of these hypotheses. We have omitted making hypotheses about partner components, since they are usually of small magnitude in family SRM studies.

Cumulative Risk and Family Process

A large body of research has described the influence of cumulative and environmental risk factors on a variety of child outcomes (Evans, Li, & Whipple, 2013). The central tenet of the *cumulative risk* perspective is that individual risks convey little harm when present in isolation, but great harm as they accumulate. In other words, the *number* of co-occurring contextual risks in a child's life (e.g. poverty, neighborhood violence, adverse childhood events, caregiver psychopathology) is linked to poorer development in a multitude of domains. These include cognitive and socioemotional functioning, attachment, academic achievement, peer relations, stress reactivity, and allostatic load (Evans et al, 2013). A comprehensive review of cumulative risk in the context of child development is beyond the scope of this paper and available elsewhere (see Evans et al., 2013), including recommendations for the employment of cumulative risk methodology in family designs (Browne, Plamondon, Prime, Puente-Duran, & Wade, 2015). However, it is important to note that a substantial component of this risk is conveyed by dysfunctional family relations (Repetti, Taylor, & Seeman, 2002). That being said, no empirical studies have examined the effects of cumulative risk across dyadic, individual and family-wide level of analysis. While it is clear that cumulative risk partially impacts developmental outcomes by making mother-child interactions less sensitive and stimulating, it is not clear how this phenomenon unfolds across multiple levels of the family. Does risk impact the entire family climate, or are particular individuals or dyads are most affected? Such questions remain unanswered due to the majority of studies employing single-dyad designs.

The Current Study

The present study examined CS during interactions amongst three dyads per family (mother-older child, mother-younger child, and sibling). Each dyad has two directional scores (e.g. mom's sensitivity towards a child and the child's sensitivity towards his or her mother). The following questions and hypotheses were articulated: *Question 1 – To what extent is sensitivity a characteristics of families, individuals, or dyads?* Consistent with the Eichelsheim et al. (2009), the SRM's on observed positivity during adolescence (Ackerman et al, 2011; Rasbash et al, 2011), and one SRM study of observed play in early childhood (Stevenson et al., 1988), we hypothesized a small family variance component and a large dyad-specific or relationship component. At the individual level, we hypothesized large actor variances for mothers, comparatively smaller actor variances for children, and small partner variances for all roles. *Question 2 - Is cumulative risk particularly deleterious for CS levels in certain relationships (e.g. parent-child, sibling)?* In accordance with research linking psychosocial risk with parent-child interactions and child behavior at the family-average and child-specific levels, we expected all relationships to be less sensitive under conditions of cumulative risk. However, we expected maternal sensitivity to be especially hampered, given the notable body of theoretical and empirical literature demonstrating the impact of contextual risk on maternal resources and mothering behavior (Belsky, 1984; Henderson, Hetherington, Mekos, & Reiss, 1996).

Methods

Participants

Multiparous women who gave birth between 2006 and 2008 in Toronto and Hamilton, Canada were considered for participation. Mothers were contacted by the *Healthy Babies Healthy Children (HBHC)* program, run by Toronto and Hamilton Public Health Units. Inclusion criteria for the intensive sample of Kids, Families & Places (KFP) was as follows: (1) English-speaking mother; (2) newborn weighing at least 1500g; (3) 2 or more children less than 4 years old in the home, including the newborn; and (4) agreement to the collection of observational and biological data. Thirty-four percent of mothers whose information was passed by HBHC consented to participate. Reasons for non-enlistment included inability to contact, ineligibility once contacted and refusals. Multiparous mothers were exclusively recruited given the focus on differentiating family-wide, individual, and relationship specific influences.

The University of Toronto Research Ethics Board approved all procedures including informed consent. We compared our initial sample (N=501) with the population of Toronto and Hamilton using 2006 Census Data of women between 20-50 years and having at least one child. Families were compared on immigrant status, number of persons in the home, family type, maternal income and education. Study families were of similar size (M = 4.52, SD = 1.01 vs. census M = 4.13, SD = 1.22) and income (median C$30,000–39,999 vs. census mean = C$30,504.16, SD = C$37,808.12). Study mothers were more likely to be Canadian born (57.7% vs. census 47.6%) and have completed a bachelor's degree or higher (53.3% vs. census 30.6%). There were fewer non-intact families among participants (5% vs. census 16.8% lone-parent families; 4.3% vs. census 10.3% stepfamilies). Of participating mothers, 56.5% identified as European, 14.6% as South Asian, 9.3% as Black, 12% as East Asian and 8.6% as other. Thus, the sample is slightly lower risk than the population based on family structure and education.

In the KFP Study, 74.1% of families were 2 child families, 18.8% were 3 child families, and the remaining 7.2% had 4 or more children. Only the youngest two children are presently considered due to the cost of observational coding and measurement burden on families. Demographics and risk variables were measured when younger children were a 2.00 months (SD = 1.06) and older children were 2.58 years (SD = 0.76); 49% of children were female. Family dyads were filmed interacting when younger children were 3.15 years (SD= 0.27), older children were 5.57 years (SD= 0.77), and 385 (76%) of families remained. Retained families were somewhat higher functioning in a number of areas (see Table 1 and Missing Data section).

Measures

Cumulative Risk. Distal psychosocial risk was measured using a cumulative risk index, which is a composite of dichotomized risk factors which indicate the number of risks present in a family's context. Cumulative risk indexes are based on the widely replicated finding that few risks in isolation convey little harm, though many concurrent risks convey great harm (Evans et al, 2013). Risk factors that were naturally dichotomous (e.g. single parent mothering) were scored as "1" or "0", where "1" indicates the presence of risk. Risks measured continuously (e.g. maternal depression) were dichotomized at one standard deviation above the mean towards the adverse pole, which corresponds to the 85th percentile based on the normal distribution (i.e. the riskiest 15% of the distribution would be given a score of "1"). A mean of all dichotomous indicators was taken, yielding a composite ranging from 0 to 1 that reflects the proportion of measured risks in a family's life. Ten risks were measured: maternal experience of any physical or sexual violence, teenage parenthood, maternal depression, single-parent mother household, marital conflict, household income less than C$20,000, no post-secondary education for mothers, poor observed neighborhood quality, and high rates of neighborhood poverty and high rates of single-parent households in the census tract area. See the Supplementary Appendix for full description of the index, which ranged from .00 to .90, (*M* = .20, *SD* = .20).

Cognitive Sensitivity. Cognitive sensitivity (CS) was assessed in a cooperative building task adapted from Aguilar et al. (2001). Each dyad (mother-younger sibling, mother-older sibling, younger-older sibling) was asked to copy a developmentally challenging design from a picture using Duplo building blocks for five minutes. Each member of the dyad was only allowed to use two of four available colors in order to promote turn taking, cooperation, and challenge. The data were directional and in a round-robin design. That is, each dyad has two directional scores, resulting in 6 cognitive sensitivity scores per family (mother→younger, younger→mother, mother→older, older→mother, younger→older, older→younger).

Sensitivity during interactions was assessed using the *Cognitive Sensitivity* (CS) coding scheme by Prime and colleagues for parent-child interactions (Prime et al., 2014; 2015). A thin slice methodology (Ambady, 2010), utilizing impressionistic ratings based on brief observations, was used to quickly assess the extent to which each individual sensitively responded to the inferred cognitive states of their interactional partner. CS is comprised of 3 underlying domains: (1) *mutuality*, which describes an individual's tendency to promote reciprocity in exchanges, evidenced by the provision of positive feedback and the encouragement of turn-taking; (2) *mind-reading*, which describes an individual's tendency to consider the knowledge of a partner, evidenced by the rephrasing of information and responsiveness to requests for help; and (3) *communicative clarity*, which describes the tendency for an individual to communicate in a way that limits ambiguity, evidenced by the provision of verbal and non-verbal directions and the promotion of a joint understanding of the goals and rules of the task. Raters were directed to watch the video of the 5-minute interaction once, use all available information, and rate quickly based on general impressions. Raters provided codes on 11 items indexing mutuality (2 items), mind reading (3 item), and communicative clarity (6 items; see Supplementary Appendix and Prime et al., 2014; 2015 for a full list of items) using a 5-point Likert scale, ranging from ‘Not at all true’ (1) to ‘Very true’ (5). A mean of the 11 items was calculated, yielding a range of 1-5.

Validation studies of the CS scales yield good psychometric properties (Prime et al, 2014; 2015). Among mothers, CS converges with traditional measures of affective sensitivity, is lower under settings of contextual risk, and is directly associated child outcomes including receptive vocabulary, executive functioning, theory of mind and academic achievement. Among siblings, CS converges with traditional measures of sibling sensitivity, and yields direct associations with child age, language, cooperation, emotion knowledge, and theory of mind. Internal consistency in the present study was α=.92 and interrater reliability was α=.84. For the sibling scheme, internal consistency was α=.90 and interrater reliability was α=.75.

Analysis

CS data were modeled using a 3-person multilevel SRM with roles (mother, older child and younger child; Kenny et al., 2006). In this design, the unit of analysis is not the individual or dyad, but the directed relationship score (i.e. six directed scores per family). Multilevel models are comprised of two general elements: (1) the *fixed* part, where parameters are analogous to coefficients in OLS regression, and (2) the *random* part, where variances reflect CS differences (in the present case) across family, individual, and dyadic components of the SRM. Modeling took place in two steps. First, a null model was fitted where estimates reflect the average levels of CS irrespective of cumulative risk. In the fixed part of the model, mean directed CS scores for each of the 6 directed relationships were estimated with corresponding 95% confidence intervals. In the random part of the model, individual effects (actor and partner) are estimated for each of the 3 roles, and dyad effects are estimated for each directed score. Actor, partner, and dyad effects are *random effects* with corresponding variances that reflect variation across individuals (for actor and partner variances), or within-individuals across relationships (dyad variances). Comparing the magnitudes of variance components allows us to ascertain the extent to which sensitivity is a function of individuals (actors and partners) or dyads (relationships). For each role, an actor-partner correlation or generalized reciprocity is also estimated. Finally, dyadic reciprocity correlations are estimated for each dyad. For example, the sibling dyadic reciprocity correlation reflects the correlation of the siblings directed scores towards one another.

In a standard 3-person SRM, it is not possible to estimate *family effects* and their corresponding variance if all other components are estimated (Kenny et al., 2006). However, alternative models are possible if certain parameters are constrained to zero. As described above, family effects were of substantive interest. Moreover, the review by Eichelsheim et al. (2009) suggests that partner variances are often modest. Presently, exploratory analyses revealed partner variances and generalized reciprocity correlations that were not significantly different than zero. Thus, we constrained the partner random effects (and their associated variances) and generalized reciprocity correlations to zero, and instead estimated a family effect and its variance.

The aforementioned null model was used to partition variance in CS attributable to the family, individual, and dyad, separately for each family role. For example, the proportion of actor variance for mothers' CS would be taken algebraically as her actor variance relative to the total variance for her expressed sensitivity (i.e. the overall family variance plus the maternal actor variance plus the average of the mother-to-younger and mother-to-older variances). By computing *Variance Partitioning Coefficients*, variability in sensitivity for each role attributable to the family, individual, and dyad can be expressed as a percentage. Furthermore, 95%

confidence intervals around these estimates can be used to communicate statistical uncertainty. Confidence intervals are approximate 95% confidence intervals derived via the Delta method (Greene, 2012). After fitting the initial model, cumulative risk will be permitted to freely impact each relationship score independently. This permits examination of the directed CS scores that are impacted by risk without imposed constraint. Furthermore, in order to determine whether cumulative risk is primarily impacting sensitivity at the family, individual, or dyad levels, proportional drops in these respective variances will be computed. See the Supplementary Appendix for an explication of the models in the current study. Furthermore, a technical appendix is included in order to outline the estimation of these models using the *runmlwin* command (Leckie & Charlton, 2013), which calls the MLwiN multilevel modelling package (Rasbash, Charlton, Browne, Healy, & Cameron, 2013) from within Stata.

Efforts have been made in self-report SRMs to include two indicators of relationship effects (Kenny et al., 2006). If this is not done, it is possible for true relationship variance to become confounded with variance due to measurement error in the response variable. In the present study, we only have one measurement of the response for each relationship (i.e. a single score on the CS scale). Where multiple indicators are available, one would add an additional lowest level into the multilevel model for the two replicate measurements of the responses, nested within each directed relationship. Eichelsheim et al (2009) achieved this by splitting original scales into two parcels and found negligible differences in results. Previous observational SRM studies have similarly relied on single composite measures (Ackerman et al., 2011; Rasbash et al., 2011), which partially operates to retain the internal consistency and psychometric properties of validated coding systems. For the current investigation, internal consistency for the response variable was very high (α=.92 and α=.90 for parent-child and sibling coding schemes, respectively). The high measurement reliability, in conjunction with the findings of Eichelsheim and colleagues (2009), suggests that our results are unlikely to be substantively affected by measurement error.

Analysis of Attrition and Missing Data

Of the initial 501 families, 385 (76%) remained at follow-up. Mothers lost to follow-up were higher risk in a number of areas, including teenage motherhood, household incomes less than $20,000, and absence of post-secondary education. The neighborhoods of non-completers were of higher risk based on observation and census linkage. Of these 385 families, there was additional missing data for CS due to children refusing to participate in the block building task (6% for mother-child dyads, 9% for sibling dyads). We addressed these additional missing data using multiple imputation (5 imputation sets) as implemented in Stata 12. We included a wide set of auxiliary variables in the imputation model to make the missing at random assumption tenable (Graham, 2009). All models were run separately across the 5 imputed datasets and results were combined according to Rubin's Rules (Rubin, 1987).

Results

See the Supplementary Appendix for basic descriptives. SRM results are provided in Table 2 and "Model A" presents SRM components irrespective of cumulative risk. In the fixed part of the model (top), it is possible to see the mean for each directed relationship. For example, CS for mothers towards younger siblings is 3.57 (95%CI = 3.49, 3.65). These means suggest that directed relationships are more sensitive when family members are older (mothers more than children, older children more than younger children). Variances are presented in the random part of the model (bottom). Estimates reflect the extent to which CS varies at the family, individual/actor, and dyad level of analysis. For example, the significant family variance indicates that there are statistically significant between-family differences in CS, or that some families exhibit consistently higher CS across all their relationships than others.

Question 1 – To what extent is sensitivity a characteristic of families, individuals or dyads?

The variances in Table 2 do not directly convey the *relative amount* to which families, individuals, or dyads influence CS, nor how this differs across roles. This is reflected in the Variance Partitioning Coefficients (see Table 3/Figure 1.) There is a significant family variance component for all family members, suggesting that some families are consistently more sensitive than others. Stated differently, unobserved family-level factors determine how CS unfolds across families, regardless of role. However, there is variability in the magnitude of the family component across roles, being relatively smaller for mothers' and older siblings', but larger for the youngest child. This indicates that family-wide factors are a more important source of variation in the sensitive behavior of youngest children compared to mothers and older siblings.

The opposite pattern is true for the individual actor variance, whereby individual factors are more important in determining CS for mothers. In other words, after accounting for family variation, some mothers are consistently more sensitive than other mothers. Furthermore, this individual variation is the *most important* source of variability in maternal CS. That is, the results demonstrate that maternal CS is primarily a function of the individual. Actor variances are also significant for older siblings, indicating that some older siblings display consistently more CS than others, on average, after accounting for family differences. However, this variance component is substantially less compared to that of mothers. There is *no* significant actor variance for youngest siblings. In other words, individual differences do *not* appear to play a role in determining how sensitive younger children are, on average, during interpersonal interactions.

Finally, there are significant and sizable relationship variances for all roles, revealing important differences in CS as a function of the dyad. That being said, this proportional variance is twice as large for children, suggesting that the unique relationship context is a more important source of variability of the sensitive behavior of youngsters versus mothers. Overall, CS during family interactions is a function of families, individuals, *and* dyads, though the relative importance of these components varies across roles. Specifically, CS of family members is more informed by individual differences when individuals are older, which may also be reflective of greater interpersonal competence (especially mothers). Conversely, the CS of children is more informed by family and dyad characteristics (especially youngest children).

Dyadic reciprocity correlations suggest that when one dyad-member is highly sensitive, accounting for family and actor differences, the other dyad-member is sensitive, in return. Correlations are calculated from the covariance and variance terms pertaining to the specific dyadic (Table 2). For example, the mother-youngest dyadic reciprocity is r = .20 (i.e. .20 = 0.03 / √ [.22*.10]). There were also significant dyadic reciprocities for mother-oldest, r = .20, and sibling, r = .49, dyads. Note that reciprocity is greater within sibling dyads (large effect size based on Pearson's r) compared to mother-child dyads (moderate effect sizes). This suggests that interpersonal contingency (in terms of CS) is greater within sibling exchanges, versus those that involve a child and a mother, which is also consistent with the large mother actor variance.

Question 2 - Is cumulative risk particularly deleterious for sensitivity levels in certain relationships (e.g. parent-child, sibling)?

Effects of cumulative risk on CS was evaluated by separately allowing each directed relationship score to vary as a function of cumulative risk (see Model B of Table 2.) For mothers, cumulative risk is associated with significantly lower CS towards both children. For older siblings, cumulative risk is associated with significantly lower CS towards younger siblings and, less so, for mothers. Finally, for younger siblings, cumulative risk is associated with significantly lower CS towards older siblings, but not mothers. Based on the pattern of fixed effects (Table 2), CS scores are *most* disrupted in situations where actors are older or in a position of competence (i.e. mothers towards children and less-so for older siblings towards younger siblings). Older siblings *are* less sensitive towards their mothers, as younger siblings are less sensitive to their older siblings, when cumulative risk is higher, though these effects are smaller. Finally, there is no measureable impact of cumulative risk on younger sibling's behavior towards mothers.

The impact of cumulative risk on CS is further elucidated via the drop in variances after entering cumulative risk into the model. Comparison of Models A and B (Table 2) reveals that the effects of cumulative risk are primarily operative at the family and individual level for mothers and older siblings. For example, 12.17% of the family variability is attributable to cumulative risk (.1217= [.0263 - .0231] / .0263; decimal places suppressed to two in tables). Conversely, 27.82% of the variability in maternal actor variance is attributable to cumulative risk (.2782 = [.3328 - .2783] / .3328), and 5.40% of the variability in the older sibling actor variance (.0540 = [.0537 - .0508] / .0537). Overall, results suggest that (1) individual components are more important for older family members, while contextual (family/dyad) components are more important for youngest children and (2) risk primarily impacts CS for mothers and older siblings and these effects are at the family and individual levels of analysis.

Discussion

The purpose of the present study was to answer the following research questions: (1) is sensitivity during family interactions in early childhood a characteristic of families, individuals or dyads, and does this vary across family roles, and (2) does cumulative risk impact the sensitivity of entire families, individuals, or specific dyads? Our findings provide novel insight into CS during real-time interactions and across the family. Furthermore, results add evidence to the principles outlined by family systems theory (Carr, 2012), existing SRM literature (Ackerman et al, 2011; Eichelsheim et al, 2009; Rasbash et al, 2011; Stevenson et al., 1988), and studies of cumulative risk and family process (Evans et al., 2013; Repetti et al, 2002).

Sensitivity operates across hierarchical levels of family organization

CS during family interactions is simultaneously a function of families, individuals and dyads, consistent with existing SRM studies of observed positivity in adolescence (Ackerman et al, 2011; Rasbash et al, 2011). However, in the current study, the size of components across roles differs from previous literature. For example, Ackerman et al. (2011) and Rasbash et al. (2011) yielded actor variances for mothers and adolescents that were sizable and similar. We observed large maternal actor variances (58%), and child actor variances were small but significant (13% for older siblings), or not statistically significant (youngest children.) Small actor components for children align with the only other observational SRM in the early years (Stevenson et al., 1988).

As hypothesized, the small or non-significant actor variances for children likely reflect the unique developmental context of sensitivity in early life. CS in children (like theory of mind and self-regulation) can be conceptualized as a developmental skill that becomes increasingly sophisticated and autonomous throughout repeated social interaction (Fernyhough, 2008; Sameroff, 2010). This ontogenic rearrangement – whereby the loci of influence transitions from the context to the organism – is implied by differences in SRM components across roles. We observe smaller actor variances when children are younger and asymmetrically influenced by others (i.e. larger family and relationship variances), and larger actor variances when individuals are older and becoming increasingly volitional (i.e. smaller family and relationship variances).

Such a pattern is consistent with theoretical models of human development, especially Sameroff's (2010) transactional regulation model and other systemic theories that emphasize the influence of increasingly bidirectional person-context interactions in shaping and canalizing internal psychological phenomena over the course of development (Blair & Raver, 2012).

Sameroff (2010) notes that "self-regulation" in early life (e.g. a child acting sensitively during challenging tasks, as measured in the present study) "mainly occurs in a social surround that is actively engaged in 'other' regulation" (p. 14). This statement is commensurate with the absence of actor variance for youngest siblings, which translates into the absence of "self" or individual-level consistency across interpersonal contexts. Moreover, "other" regulation may take the form of modeling and guidance from mothers or older siblings, who may be relatively stable in their behavioral (i.e. actor effects) or may adjust to the particular relational demands (i.e. dyad effects). Other-regulation may also appear as an ambient family climate, consistent with the conceptualization of families as emergent and systemic entities made up of constituent parts (Carr, 2012; Jenkins & Bisceglia, 2011), empirical and theoretical discussions of family-wide functioning (Epstein, Baldwin, & Bishop, 1983; Georgiades, Boyle, Jenkins, Sanford, & Lipman, 2008), and previous findings from family SRMs (Ackerman et al, 2011; Eichelshiem et al, 2009; Rasbash et al, 2011). Indeed, family components were approximately three-times larger for youngest children versus older children and mothers in the present study. In sum, and unlike single-dyad research, the current study reveals that the developmental impact of sensitivity on young children occurs at the ambient family level in addition to the unique dyadic context.

Over time, the transactional co-regulation of self and other becomes increasingly embedded within the individual (Sameroff, 2010). This permits the emergence of relatively consistent social scripts and intentional behavior across interpersonal contexts – behavior that is rooted in autonomous psychological regulatory capacities that evolve via relationships (Bernier et al., 2012; Blair & Raver, 2012). This could reflect the "development" of actor effects (i.e. cross-context consistency) throughout early childhood via reciprocal family relationships. Microgenetic longitudinal SRM research in early life is needed to fully test this hypothesis.

Large maternal actor variances are consistent with non-SRM developmental literature which highlights the person-level variability of maternal behavior. For example O'Connor and Croft's (2001) behavioral genetic study of attachment security in preschool twins demonstrated that 32% of the variability in attachment security was attributable to the shared environment (and notably, there was not a significant genetic component). Authors concluded that environmental concordance in attachment may be attributable to twins' similar experiences of maternal sensitivity. Stated differently, maternal sensitivity was deemed to be largely a function of maternal factors. Similar findings have been observed in studies of differential parenting, where approximately half of the variance in sensitivity is attributable to mothers (Browne et al., 2012). Moreover, large maternal variance effect *is* consistent with self-report SRM's of maternal affect (Eichelsheim et al, 2009). Furthermore, results are consistent with a multitude of single-dyad research, where variability in sensitivity is explained by a variety of maternal characteristics and experiences including exposure to childhood adversity (Berlin, Appleyard, & Dodge, 2011), poor psychological functioning (Elgar, McGrath, Waschbusch, Stewart, & Curtis, 2004), personality (Clark, Kochanska, & Ready, 2000), and genetic polymorphisms (Bisceglia et al., 2012). Moreover, because parenting in single dyad studies is relatively stable some scholars have described sensitivity as trait-like over time (Madigan, Plamondon, Browne, & Jenkins, 2016). Interestingly, Stevenson and colleagues (1988) did *not* find large actor variance for mothers, possibly due to methodological differences whereby six specific types of play were coded (versus a global rating of sensitivity). This may have resulted in the uncovering of proportionally larger relationship variances across different domains.

Impact of cumulative risk on sensitivity across hierarchical levels of the family

Cumulative risk particularly impacts CS for older family members or those in a position of relative competence (i.e. mothers to children, older to younger sibling). This finding is consistent with arguments suggesting that cumulative risk recapitulates from the distal environment to the proximal context. That is, environmental adversity "gets inside the family" and impacts the interpersonal behavior of family members (Browne et al, 2015; Repetti et al, 2002), particularly mothers and older children. This appears to occur in a "spillover" fashion (Nelson, O'Brien, Blankson, Calkins, & Keane, 2009), whereby adversity and stress in one family setting (i.e. the contextual environment) directly transfers to another setting (i.e. the proximal interpersonal behavior of mothers and children). Other studies have identified spillover effects linking family adversity and family interpersonal climate. For example, parents are more socially and emotionally withdrawn, distracted, angry, irritable, and less responsive towards the entire family after having a stressful day (Repetti, Wang, & Saxbe, 2009). Analogous spillover processes have been observed for structural family risks. That is, parents who report higher levels of marital dissatisfaction and household chaos also report being less supportive and responsive to their children's negative emotions (Nelson et al, 2009).

The present investigation extends the spillover literature, demonstrating that this phenomenon is occurring in a downward-cascade fashion. That is, risk exhibits the greatest influence on the directed sensitivity scores of interpersonal counterparts who are older and in a relative position of competence or authority, both between generations (mothers to children) and within generations (older to younger siblings). Moreover, this spillover is occurring across levels of family organization, whereby the effects of risk are primarily operative at the family level and at the individual or actor level for mothers and older siblings. Similar to the current findings, Repetti and colleagues (2009) have identified spillover effects for children, where youngsters report more aversive relational experiences at home during social and academic difficulties at school. This may especially be the case for older siblings, given their increased responsibility for guiding the interpersonal interactions with younger, and perhaps less competent, siblings.

Environmentally-induced stress reactions and negative mood enters the home due to the direct transfer of these states from one setting to another (Evans et al, 2013; Story & Repetti, 2006). Contextual adversities also deplete psychological resources over time. That is, coping facility is exhausted while negotiating challenge outside the home, making individuals less capable of navigating and managing family interactions (Hetherington & Blechman, 2014). This likely explains the patterning of findings, whereby cumulative risk is most impactful on sensitivity that operates down the age gradient. It is the challenging role of more advanced family members to guide younger individuals through complex social interactions. Indeed, previous literature has demonstrated that maternal scaffolding behavior is lower when mothers have less formal education (Carr & Pike, 2012). The current study extends the link from social disadvantage to sibling sensitivity. That is, the double-disadvantage for youngest children in risky homes complements findings surrounding family resource dilution and risk associated with the birth of additional children (Downey, 2001). In other words, younger children experience less sensitivity from both mothers and siblings under settings of risk.

Limitations and Future Directions

The current study benefited from a large and multi-dyad family sample, observational data, and informative methodology. That being said, there are limitations that should be addressed in future studies. First, data on certain dyads were unavailable (i.e. marital, father-child etc.) Future SRM studies should broaden measurement in order to increase generalizability, and consider other dyadic factors that may influence results (e.g. sibling gender). Secondly, there is a need for SRMs of observed warmth and conflict during childhood. Thirdly, the present study employed a single indicator for each directed relationship, preventing the separation of true relationship variance from measurement error. The high internal consistency of CS and analyses by Eichelsheim et al. (2009) suggest that results would be the same if multiple indicators were available. Moreover, in terms of unaccounted measurement error, the relationship variances in the present study would be *overstated* and the relative importance of family and actor variances (which were found to be sizable and significant) would be *understated*.

Prior to this study, the manifestation of CS across the family system was unclear, in addition to the impact of risk on CS across the levels of the family. The present findings have revealed complementarities between family systems theory and relational models of development by demonstrating the primacy of family and dyadic influences on CS for young children, in addition to the individual-level canalization of such phenomena over time. In conjunction with the "trickle-down" influence of risk on younger siblings, findings from the current study call for family-wide *and* dyadic interventions. In other words, it is possible that parent-child interventions (e.g. Landry et al., 2008; Lieberman & Van Horn, 2004) could be effectively augmented by considering family-wide processes, in addition to the incorporation of other dyads. Future studies that address these areas will continue to shed light on the way in which interpersonal processes unfold across levels of family organization, and the manner in which cumulative risk disrupts harmonious exchanges within the family system.

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Table 1

Demographics for study participants (Time 3; N=385)

	N (%)
Caucasian	223 (57.9)
South Asian	54 (14.0)
Black	28 (7.3)
East / Southeast Asian	51 (13.2)
Other	29 (7.6)
Married / Cohabitating	354 (91.9)
2 Child Family	234 (60.8)
3 Child Family	106 (27.5)
4 or More Child Family	45 (11.7)
	M (*SD*)
Mom Education (Years)	15.53 (2.46)
Partner Education (Years)	15.64 (4.66)
Family Income (Median)	$75,000 to $84,000
Mom Age	36.15 (2.71)
Partner Age	39.35 (4.66)

Table 2

Results from a 3 Person Social Relations Model (mom, younger sibling [S1], older sibling [S2])

	Model A (null model)			Model B		
Parameter	Estimate	(95%CI)		Estimate	(95%CI)	
Fixed-part						
Mom➔S1	3.57**	(3.49,	3.65)	3.83**	(3.73,	3.93)
Cum. Risk				-1.40**	(-1.78,	-1.02)
Mom➔S2	3.48**	(3.40,	3.55)	3.71**	(3.61,	3.80)
Cum. Risk				-1.24**	(-1.61,	-0.88)
S2➔S1	2.72**	(2.65,	2.79)	2.86**	(2.76,	2.96)
Cum. Risk				-0.76**	(-1.17,	-0.35)
S2➔Mom	1.80**	(1.74,	1.86)	1.85**	(1.77,	1.94)
Cum. Risk				-0.29**	(-0.61,	0.03)
S1➔S2	1.83**	(1.79,	1.88)	1.89**	(1.82,	1.97)
Cum. Risk				-0.32**	(-0.62,	-0.02)
S1➔Mom	1.36**	(1.32,	1.39)	1.37**	(1.32,	1.42)
Cum. Risk				-0.07	(-0.27,	0.12)
Random-part						
σ^2 (Family)	.03**	(.01,	.04)	.02**	(.01,	.04)
σ^2 (Mom Actor)	.34**	(.27,	.40)	.28**	(.23,	.34)
σ^2 (S2 Actor)	.06**	(.02,	.09)	.05**	(.02,	.09)
σ^2 (S1 Actor)	.00	(-.01,	.02)	.01	(-.01,	.02)
σ^2 (Mom➔S1)	.22**	(.17,	.27)	.22**	(.16,	.26)
σ^2 (Mom➔S2)	.15**	(.10,	.20)	.16**	(.11,	.21)
σ^2 (S2➔S1)	.41**	(.33,	.48)	.40**	(.32,	.47)
σ^2 (S2➔Mom)	.28**	(.22,	.33)	.29**	(.23,	.34)
σ^2 (S1➔S2)	.20**	(.16,	.23)	.19**	(.16,	.23)
σ^2 (S1➔Mom)	.10**	(.08,	.12)	.10**	(.08,	.12)
σ(Mom/S1)	.03*	(.00,	.05)	.03*	(.00,	.05)
σ(Mom/S2)	.04*	(.00,	.07)	.04*	(.00,	.07)
σ(S1/S2)	.14**	(.10,	.18)	.14**	(.10,	.17)
Deviance	3692.10			3620.78		

* $p < .05$, ** $p < .01$, σ^2 = variance, σ = covariance.

Table 3

Variance partitioning results examining the proportion of sensitivity for each role attributable to family, actor or dyad effects

	Variance partition coefficient	
Role	Estimate	(95%CI)
Mother		
Family	0.05**	(0.02, 0.08)
Actor	0.58**	(0.52, 0.65)
Dyad	0.37**	(0.31, 0.43)
Older Sibling		
Family	0.06**	(0.03, 0.10)
Actor	0.13**	(0.04, 0.21)
Dyad	0.81**	(0.72, 0.90)
Younger Sibling		
Family	0.16**	(0.08, 0.25)
Actor	0.02	(-0.08, 0.12)
Dyad	0.81**	(0.72, 0.91)

* $p < .05$, ** $p < .01$.

Note: Variance estimates are taken from Model A in Table 1 (i.e. the null model). Approximate 95% Confidence intervals were derived using the Delta method.

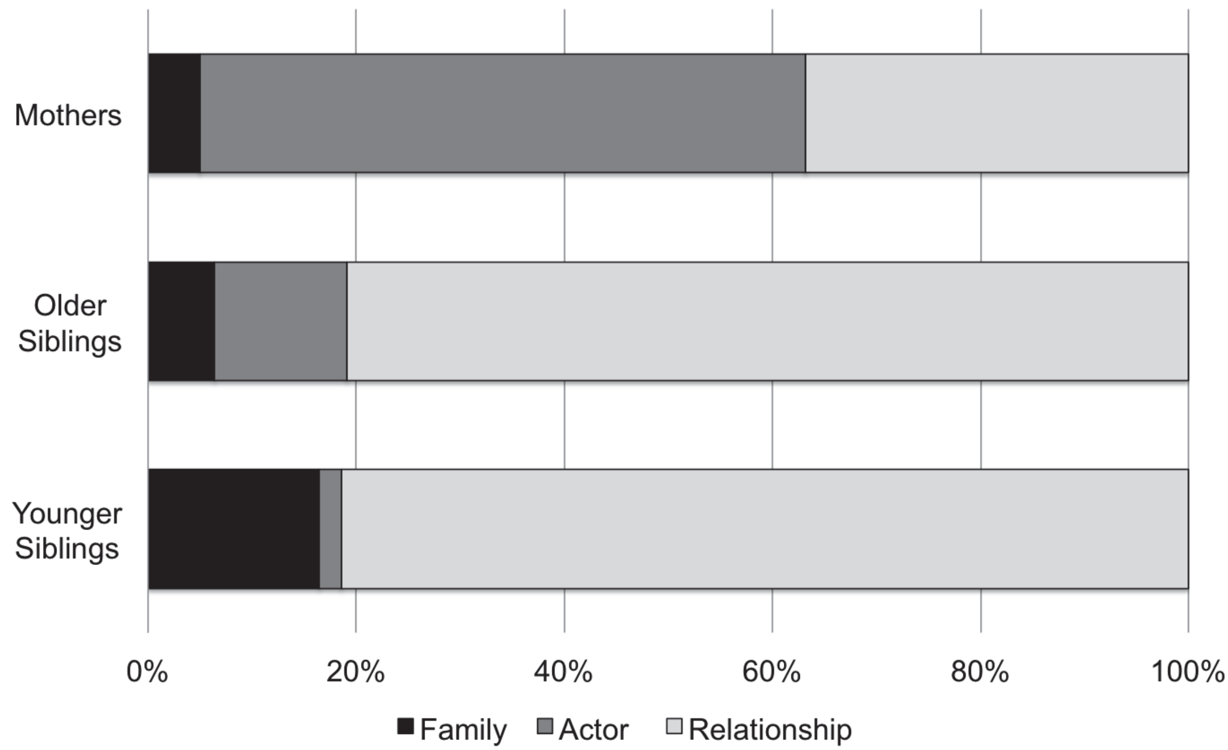

Figure 1. Proportion of cognitive sensitivity attributable to Social Relations Model components as a function of family role.