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The effects of home visiting on mother-child interactions: Evidence from dynamic micro-level data

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Abstract

This study examines the effects of a home visiting program for first-time disadvantaged mothers on mother-child interactions. A sample of 109 dyads participating in the Pro Kind trial was videotaped during a 3-min typical play situation at the participants' homes when the child was aged 25 months, and assessed for orientation and contingency. The results show a significant improvement of the interactions between girls and their mothers, by increasing both the persistence of girls' positive behaviors (even in the absence of mothers' positive behaviors). No positive impacts were detected for the boys. These results have important implications for the analysis of mother-child interactions data and the design of home visiting programs.

Keywords: Home Visiting; Randomized Trial; Mother-Child Interaction; Dynamic Micro-coding systems

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Introduction

Early experiences can have a lasting impact on a child's long-term cognitive, socio-emotional and health development. Children born in more vulnerable families risk failing to reach their developmental potential, in part because they are exposed to unstable, unsafe and non-stimulating environments during some of their most formative years (e.g., Bradley, et al., 2001a, 2001b; Almond, et al., 2018). In many countries home visiting programs present an important early childhood policy to support vulnerable families with young children, and several studies show that these programs are effective in promoting child development (for reviews and meta-analyses see Sweet & Appelbaum, 2004; Avellar & Supplee, 2013).

Almost all home visiting programs aim to support infant-parent relationships, as well as sensitive parenting, and most are grounded in attachment theory (Berlin et al., 2017; Harding, et al., 2007; Olds, 2006). It is hypothesized that parents who respond to signals from their children and address their physical, emotional, and behavioral needs in a warm and sensitive manner establish a basis for a secure attachment relationship (Ainsworth, et al., 2015; Berger, et al., 2007; Calkins & Hill, 2007; Sroufe, 1997). The degree to which children form a secure attachment relationship with a caring, responsive, and sensitive adult influences children's trust in the world, which in turn positively affects children's self-representation, relationships, cognitive, and psychological development (Sroufe, 1979; West, et al., 2013; Berlin et al., 2017).

The present study provides the rare opportunity to directly examine the effects of a home visiting program, the *Pro Kind* Program, on sensitive and empathic maternal care and mother-child relationships in a randomized controlled trial (RCT). *Pro Kind* is the German adaptation of the Nurse-Family Partnership (NFP), an evidence-based home visiting program for disadvantaged first-time mothers, which starts during pregnancy and continues until the second birthday of the child (Olds, 2006). Our measure for maternal care and mother-child relationships relies on systematic and objective in-home observations of the mother and child's micro-level interaction sequences during typical play

situations. These sequences were videotaped and sequentially coded, allowing for the analysis of static *and* dynamic responses.

In brief, besides increasing parenting competencies, *Pro Kind* aimed at improving a range of other factors, such as: maternal prenatal health (by reducing risky health behaviors such as smoking), child health and development (for example by preventing accidents and reducing child abuse and neglect), family functioning, and economic self-sufficiency. Previous evaluations of the program have found positive effects on child cognitive development and maternal investments – both concentrated in girls – on certain maternal skills and mental health (Sandner & Jungmann, 2017; Sierau et al., 2016; Sandner et al., 2018). Additionally, Sandner (2017) has showed that the treatment increased second births and reduced employment for the home-visited mothers, most likely because the intervention increased satisfaction with the maternal role in the treatment group. Until now, there has been no research on the impact of *Pro Kind* on mother-child interactions using objective video measures.

Previous studies investigating the effects of home visiting on sensitive parenting have often relied on maternal-reported questionnaires (e.g., LeCroy & Lopez, 2018; Green et al., 2014). Yet, the validity of self-reported measures is problematic both for the presence of subjective components, and because of the tendency of the parents to respond in a socially desirable manner, which is strongly evident in behavior ratings (Eddy, et al., 1998; Gardner, 2000). The issue of validity may be exacerbated in populations with multiple risk factors (Sandner & Jungmann, 2016). Fortunately, to obviate these problems, some RCTs evaluating home visiting programs, including Healthy Families New York (HFNY; DuMont et al., 2010), Early Head Start (EHS; Love et al., 2005), and NFP (Olds et al., 2002, 2004), have used observational measures based on video recordings to analyse intervention impacts on mother-child interactions.

Results from videotaped observational assessments in the NFP's Denver randomized trial indicate that mothers who were offered home visitation, either by nurses (Olds et al., 2002) or paraprofessionals (Olds et al., 2004), showed higher levels of responsiveness than mothers in the

control group. Similarly, based on videotaped sessions of a semi-structured play task, the evaluators of EHS reported program impacts on the quality of assistance and levels of supportiveness offered by mothers (Love et al., 2005). The study on HFNY found that home visiting fostered positive parenting, such as maternal responsiveness and cognitive engagement, and reduced harsh parenting (Rodriguez et al., 2010). The first two studies used coding systems in which one video session represented one coding unit (known as global coding system) to assess mother-child interactions. The study on HFNY, instead, used a coding system with 10-second intervals (known as micro coding system) adopting the frequency of certain child or mother behaviors as indicators of the mother-child interaction quality.

Although these previous approaches have significantly improved the coding of mother-child interactions, they either only coded the observational video data globally (in the case of NFP and EHS), or they simply counted frequencies of certain behaviours (in the case of HFNY), and in all cases they focused on mothers. However, as research on sensitive parenting measures shows, only micro coding systems considering dynamic reactions of *both* mother *and* child, have the potential to reveal complex patterns of interactions (Bardack et al., 2017; Floyd, 1989; Markman & Notarius, 1987). For example, Bardack et al. (2017) found that micro coded measures of mother-child interactions independently predicted fewer externalizing and inattentive/impulsive behaviors in school, whereas global-coded measures did not. Their findings illustrate the importance of using dynamic measures of interaction in the context of micro coding systems.

Furthermore, global coding systems may be susceptible to systematic rater bias, as they require the coder to make complex, subjective judgments to produce ratings that summarize behaviors across lengthy observational periods. By comparison, micro coding represents a low-inference approach, as these coding schemes divide moment-to-moment behaviors into small units, leaving little room for subjective rater judgments (Bardack et al., 2017; Alexander et al., 1995; Markman & Notarius, 1987). In recent years, researchers have been applying different methods to code observational mother-child interaction video data, since it has become increasingly apparent that global coding schemes are not

sufficient to capture all the aspects of dyadic interactions (see for example Bohr et al., 2018). Each coding scheme focuses on a particular aspect of mother-child interactions. For example, Davidov and Grusec (2006) identify parental warmth and responsiveness to child distress as two separate indicators for parental interaction behavior. Their results, based on global coding measures, show that parental responsiveness to distress is central to the development of attachment security and to self-regulation of stress, whereas warmth might be more involved more in the development of social reciprocity.

The approach used in this study is to measure mother-child interactions within an objective dynamic micro coded system, which considers actions and responses of both, children and mothers, in 5-second coding intervals. Therefore, we capture important aspects ignored by previous home visiting trials, which only used global measures of mother-child interactions or static micro measures that simply counted frequencies and only focused on mothers. Since the *Pro Kind* study is the first to use such a dynamic micro coding approach within a randomized trial, the present work provides both a methodological and a substantive contribution to the literature on the effects of home visiting programs on mother-child interactions.

We conduct all our analysis separately for boys and girls. We chose this gender-specific approach since previous evaluations of early interventions have found significant differences by gender, often uncovering greater impacts for girls. For example, for center-based interventions, Anderson (2008) examines three influential randomized trials – the Abecedarian, Perry, and the Early Training Project – and finds that girls garnered substantial short- and long-term benefits from the interventions, but there were no significant long-term benefits for boys. Garcia et al. (2018) find that, in the Abecedarian intervention, girls have a greater number of statistically significant treatment effects than boys, and effect sizes for them are generally bigger. As sources of these differences, they show that the home environment for girls is worse, leaving greater scope for improvement by the programme. Nores et al. (2019) show that the benefits of the AeioTu interventions are greater for girls than for boys.

In case of home visiting programmes, Eckenrode et al. (2010) find greater treatment effects for girls than for boys (especially for reductions in crime) in the NFP Elmira trial; Sidora-Arcoleo et al. (2010) show that the NFP Memphis trial reduced the prevalence of physical aggression at age 2 only in girls; and Lorber et al. (2019) find that the NFP Denver trial moved girls from high to moderate externalising behavior, with no impact on boys. For the *Pro Kind*, Sandner and Jungmann (2017) find that the effects on cognitive development were larger for girls, a results which might be attributed in part to higher dosage (mothers of girls received 10% more home visits). Similarly, Vallotton et al. (2012) find that Early Head Start improved children's expressive language for girls, but not for boys.

This intervention evidence is consistent with recent animal evidence showing that the social environment has a significant impact on neuroplasticity and behavior particularly in females (Faraji et al., 2018), and that early life stress affects social interactions and prefrontal cortex dendritic morphology only in female rats (Farrell et al., 2016). This evidence supports the existence of a biological channel. For what concerns parental behavior, a recent meta-analysis (Endendijk et al., 2016) has reported very few differences in parental use of control in boys versus girls. However, the authors have noted that the effect sizes for controlling strategies were largest in studies with children between 0 and 2 years of age; and that there were historic changes in child rearing, with a greater preference for, and involvement in, daughters after the 1990s. Mesman and Groenevald (2018) also note that, although gendered parenting is rarely explicit (e.g. for desirability concerns in equalitarian societies), it is often implicit, i.e. parents respond to children's behaviors differently depending on gender. The authors "advocate for a revival in studying gendered parenting", using observational rather than self-reported measures: our work answers to such call.

Intervention and Participants

In this study we test the effectiveness of home visiting in improving mother-child interaction using a randomized controlled trial of the *Pro Kind* program. This is an adaptation of the well-known NFP program, which provides to the local implementers teaching material, guidebooks, and

instructions regarding the frequency and content of the home visits, and the selection of the home visitors (see Jungmann et al., 2009; Sierau et al., 2015; Olds, 2006 for more information about the *Pro Kind* project and NFP). The *Pro Kind* intervention starts between the 12th and 28th week of pregnancy, and continues up to the child's second birthday. The frequency of the home visits varies between weekly, biweekly, and monthly according to the NFP model prescription, with the highest frequency directly before and after birth. Overall, a maximum of 52 home visits with an average duration of 90 minutes each are scheduled between pregnancy and the child's second birthday. Teaching materials and visit-by-visit guidelines, adapted from NFP, structure the theme and aim of each home visit. Similarly, as in the NFP, the theoretical concept of the *Pro Kind* intervention is based on human attachment theory (Bowlby, 1969), human ecology theory (Bronfenbrenner, 1979) and the concept of self-efficacy (Bandura, 1982). Brand and Jungmann (2012, 2014) provide a further description of program design and implementation.

In the original *Pro Kind* trial 755 expectant mothers in three federal states (Lower Saxony, Bremen and Saxony) were enrolled. All of them were financially and socially disadvantaged with at least a basic understanding of the German language. Financial disadvantage in the *Pro Kind* context is mainly defined as receiving social welfare benefits, while social disadvantage refers to the presence of risk factors such as, for example, low education, teenage pregnancy, and health problems. The baseline randomization was successfully conducted by a computer routine based on Efron's biased coin approach (Efron, 1971) stratified by municipality, maternal age (< 18 vs. > 18 years old), and maternal nationality (German vs. non-German).

At 24 months after birth, 346 of the mother participated in a follow-up interview (see Sandner et al. 2018 for a flow diagram and exact reasons for non-participation). At this follow-up point videotapes were recorded in Lower Saxony and Bremen with 150 randomly chosen mother-child pairs. Due to limited resources, it was not possible to record more video sequences. Video sequences of 42 mother-child pairs were excluded from coding because they were shorter than three minutes, leaving an

analysis sample of 109 mother-child pairs with coded videos. Table 1 reports the baseline characteristics of the mothers and their children (54 boys and 54 girls) included in the analysis.

Table 1 shows that the analysis sample is well balanced, with no significant differences at 5% significance level between observed characteristics in the treated and the control group (Columns 1-3) as well as between girls and boys (Columns 4-6). The women in our analysis sample are in general similar to those in the baseline sample, although they have slightly higher income in the analysis sample (Columns 7-9). In additional analyses (results not reported), we have been able to reproduce the key results by Sandner and Jungmann (2017), namely that the intervention reduced the prevalence of developmental delays at 12 months in girls only. Similar to the whole sample, the families included in our analysis sample received 46.79 (SD=8.92, range: 13-63) home visits on average while the control group received 0 home visits.

Measures

For the analysis of intervention effects on mother-child interactions, examiners videotaped typical interaction situations at the participants' homes for a duration of three minutes. The mothers were asked to play with the children without being given any specific interaction task. All examiners were female research assistants (studying psychology or special needs education) who received standardized training and ongoing supervision in interviewing techniques and developmental testing from research staff.

Two persons coded the videotaped play situations, following an adaptation of the *Mannheim rating scale for the analysis of mother-child interactions in toddlers* (MRS-MCI-T; Dinter-Jörg et al., 1997). The two coders were intensively trained in using the MRS-MCI-T for rating and reached high rater-trainer reliability after the training (Kappa .86-.87). The software *Interact*, a computer-based video analysis tool, was used for all video ratings. All examiners and coders were blinded to the treatment condition.

Scales

For our analysis of mother child-interaction, we examine the scales *Orientation* and *Contingency* which are included in the MRS-MCI-T. One coder rated both scales for mothers and children separately. The coders rated the scales following the recommended order of the MRS-MCI-T guidelines, one after another separately for mother and child, for all the 109 videos. Coder A rated 78 videos and coder B rated 31 videos.

The coding interval for *Orientation* contains 5 seconds. Crucial for the coding process was the focus of the main attention of the subject within the interval; this was observed by considering three aspects: direction, verbal expression and hand and body motion. For our analysis, we generated a binary variable coded as 1 when the orientation was on the play situation and the partner, and as 0 if the orientation was on neither one of the two.

Contingency captures all direct and distinct reactions (positive, negative, initiation of interaction and also lack of reaction) to the partner's behavior in the 5-second coding interval. We generated two binary variables. The first takes value 1 if the child or the mother showed *Positive Contingency* (including initiation of interaction, (e.g. the child smiled at the mother)) and 0 if otherwise, the second takes value 1 if the child or the mother showed *Negative or Lack of Contingency (*e.g. the child reacts crying to an action of the mother or the mother does not react if the child wants to be held) and 0 if otherwise. The residual intervals are those in which the mother and child showed no interaction (e.g. both are playing with the toy but they are not interacting). Overall, the aim of the *Contingency* rating is to measure not synchronic behavior, but rather the reciprocity of the interaction.

In line with Davidov and Grusec (2006), we believe that maternal responses to child actions are an important part of understanding parental interaction behavior. However, to give a complete picture of mother-child interactions, it is also crucial to consider child responses to maternal actions and the dynamic interdependency of parent-child actions. To capture dynamic mother-child interactions, as mentioned above, we focus on the maternal and child behaviors *Orientation* and *Positive* and *Negative Contingency.* We interpret *Orientation* (on the play situation and the partner) and *Positive Contingency*

as positive behaviors, while we interpret *Negative Contingency* as negative behavior. We choose these three behaviors because changes in *Orientation* and *Contingency* in one partner likely provoke a reaction in the other partner.

To examine the validity of our mother-child interaction measures, Table 2 shows that our positive behavioral outcomes (*Orientation* and *Positive Contingency*) for the child correlate positively with cognitive development (measured by the Bayley Scales of Infant Development II (BSID-II)) and negatively with low birth weight (birthweight < 2500g); for the mothers, they correlate negatively with depressive symptoms (measured by the Depression Anxiety Stress Scale (DASS)), especially for mothers of boys. Lastly, children of higher birth weight and better cognitive development are less likely to display negative/lack of contingency.

Interaction scenarios

To test the dynamic interdependency of parent-child actions, we use four scenarios in which we investigate how one partner reacts to the behaviour, which the other partner showed in the previous period. The first scenario represents a strongly stable situation, in which we investigate how the child or the mother reacts if both partners showed positive behavior in the previous period. The second scenario represents a strongly unstable situation, in which we investigate how the child or the mother reacts if both partners showed negative behavior in the previous period. The third and fourth scenarios represent a partly unstable situation, in which we investigate how the child or the mother reacts if one of the partners showed positive and the other negative behavior in the previous period.

The first scenario is interesting because it characterises mother-child interactions where both partners start with positive behavior. If one partner shows negative behavior in the next period this might be a strong indicator of unpredictable and dysfunctional mother-child interaction. The second scenario studies whether in a stressful situation, where both partners show negative behavior, they are able to revert to positive behavior. The last two scenarios are informative because they investigate whether the partner with the negative behavior or the partner with the positive behavior has a more

dominant effect on the behavior of the dyad in the next period. For example, the scenarios show whether the mother (who showed positive behavior in the previous period) is able to bring her child (who showed negative behavior in the previous period) back to positive behavior: this might be a sign of positive trustful mother-child interaction.

Statistical Analysis

In a first step, we perform a more traditional analysis, by examining *static* treatment effects on the six scales (*Orientation, Positive Contingency, Negative or Lack of Contingency,* separately for the child and the mother) using two alternative methods. First, we estimate a Probit model separately for each outcome scale (where the outcome is a binary variable taking value 1 if the behavior is observed in the coding interval), using the treatment dummy as a covariate indicating treatment allocation against control and clustering the standard errors to account for repeated observations for each individual. Second, we aggregate the occurrence of 1's for each individual, multiply them by the time they correspond to (so each 1 is transformed into 5 seconds, which, summed all together, give the frequencies of certain behaviors) and fit a linear regression model using the treatment dummy as a covariate. We fit all models separately for girls and boys and test for gender differences using the Wald test. For the linear regressions, we directly report the coefficients, whereas for the Probit models we report the average marginal effects.

In a second step, we perform a novel *dynamic interaction analysis* using the three binary scales (*Orientation, Positive Contingency*, *Negative or Lack of Contingency*) to explore the effects of the intervention on the persistence and the dynamics of mother-child interactions, as described above. For every set of outcomes, we *simultaneously* model the mother and respective child outcome to account for correlation in the error terms between the two, using cross-lagged panel probit models. In each equation, we include as covariates: the first lag of the outcome, the first lag of the partner's outcome (child's or mother's depending on whose outcome is modelled), the binary variable Treat and the interactions of Treat with each of the two lags (to allow for the effect of the intervention to vary with

the behavior of the partner in the previous period). Full model equations can be found in the Supplemental Material.

The results are presented for the four previously described scenarios ("Both", "None", "Child", and "Mother",) for which the Supplemental Material contains the full results. In scenario "Both", mother and child, show positive behaviors in the previous period. In scenario "None" neither mother nor child showed positive behaviors. In the scenarios "Child" and "Mother" either the child or the mother shows positive behavior in the previous period. Table 3 gives an overview about the scenarios where the columns show the three behaviors of interest *(Orientation, Positive Contingency, Negative or Lack of Contingency)* and the rows show the four scenarios.

Results

We present the results separately for the static treatment effects and the dynamic interaction analysis in the next two sections.

Static Analysis

Table 4 presents the treatment effects for each of the six outcomes for the sample as a whole, and separately for girls and boys. The first four columns refer to the Probit models and the other four columns to the OLS models. The intervention led to a 15 p.p. (p =.001) increase in the likelihood of a girl being oriented towards the task and the mother during the play situation, against a control group mean of 48%; no effect was detected for the boys. The intervention also led to a significant 3 p.p. (p = .024) decrease in the likelihood of having negative (or lack of) contingency for the girls with respect to a control group mean of 6% (hence a 50% reduction); again, no impact was detected for the boys. No significant impact was detected on the likelihood of positive contingency. The treatment effects for girls on orientation and negative (or lack of) contingency remain strong and significant when examining the outcomes in their aggregate form. The girls in the treatment group were oriented towards the task and the mother for 27 seconds (p = .002) longer than the girls in the control group during the play situation. In addition, they were in negative (or lack of) contingency for 6 seconds (p = .022) less

than the control group girls. The Wald tests confirm that the differences between the treatment impacts for girls and boys for orientation and positive contingency are significant, with values of $\chi^2(1) = 9.47$ ($p = .002$) and $\chi^2(1) = 3.63$ ($p = .057$) respectively; results are inconclusive for negative contingency. No treatment impacts were detected on mother orientation and contingency.

Dynamic Analysis

We then proceed with the results from the dynamic analysis using the cross-lagged panel probit models. In this section, we present the predicted probabilities for the four scenarios for girls and for boys, for children and mothers, and for treatment and control groups. The Average Marginal Effects for each variable for each equation entering the models are presented in Tables A1-A3 in the Supplemental Material. These tables also report, for each model, the estimated parameter rho, which is an estimate of the correlation between the error terms of the two equations. A large (small) value of rho is indicative of strong (weak) dependence between the two outcomes, whereas in case rho is zero the two outcomes are independent and each equation could be estimated separately (since there is no efficiency improvement by the joint estimation). We see that rho is almost always significant, which justifies our modelling choice.

The predicted probabilities (there are no out-of-sample predictions) are presented in Tables 5-7, one table for each outcome. In each Table, there are four panels, one for each scenario. In each panel, the first and second columns show the conditional marginal effects for the control and the treatment groups, respectively; the third column shows a Wald test on their difference In the rows, the effects of the hypothetical scenarios are first displayed for the girls, separately for children and mothers, and then for the boys, again separately for children and mothers.

Table 5 shows the results for the models for *Orientation* in the play situation (orientation on the task and the partner). Looking at the most positive scenario, “Both” (the one where both, the child and the mother, were oriented towards the task and the partner in the previous interval), the girls in the control group have a probability of 67% (*SE* = 0.04, 95% CI [0.60, 0.75]) to be oriented towards the

task and the mother in the next time interval, whereas the girls in the treatment group have a 76% probability (*SE* = 0.02, 95% CI [0.71, 0.81]). The difference is significant with $\chi^2(1) = 4.07$ ($p = .044$). For the mothers, the probabilities are 92% (SE=0.01, 95% CI [0.89, 0.95]) and 95% (*SE* = 0.01, 95% CI [0.93, 0.98]) for the treatment and the control group respectively, with the difference being significant ($\chi^2(1) = 2.93$, $p = .087$). In contrast, the probabilities for boys (74%, *SE* = 0.03, 95% CI [0.67, 0.80]) and their mothers (94%, SE=0.02, 95% CI [0.90, 0.97]) in the control group are higher than the treatment group (67%, *SE* = 0.05, 95% CI [0.56, 0.78] and 87%, *SE* = 0.03, 95% CI [0.81, 0.93]), with only the latter being marginally significant ($\chi^2(1) = 3.68$, $p = .055$). For the scenario "None", where all the behaviors are fixed at their negative values for the previous period, none of the differences are significant. Also, non-significant results are obtained for the "Child" scenario, whereas for the "Mother" scenario, there is a significant difference ($\chi^2(1) = 9.83$, $p = .002$) for girls, with the control group having 34% (*SE* = 0.03, 95% CI [0.28, 0.39]) and the treatment group 48% (*SE* = 0.04, 95% CI [0.41, 0.55]) probability that the girls are oriented towards the task and the partner when the mother showed positive behavior and the child herself negative behavior in the previous period.

Table 6 presents the results for *Positive Contingency*. Under the scenario "Both", the girls have 65% probability of showing positive contingency in the present period (*SE* = 0.03, 95% CI [0.59, 0.71]) in the control group, whereas in the treatment group they have 73% (*SE* = 0.02, 95% CI [0.69, 0.78]) probability, the difference being significant ($\chi^2(1) = 5.47$, $p = .019$). For mothers we detect no significant difference. In contrast to this, and as for the previous outcome (orientation), the treatment has a negative impact on the boys and their mothers. The control group has 71% (*SE* = 0.03, 95% CI [0.64, 0.78]) and 78% (*SE* = 0.04, 95% CI [0.70, 0.85]), and the treatment group has 59% (*SE* = 0.04, 95% CI [0.50, 0.68]) and 65% (*SE* = 0.04, 95% CI [0.58, 0.72]) probability of positive contingency for boys and their mothers, respectively. For both of them the differences are significant with $\chi^2(1) = 4.66$ ($p = .031$) and $\chi^2(1) = 6.00$ ($p = .014$), respectively. In all the other scenarios ("None", "Child" and "Mother"), there are no significant differences, apart from the girls in the "Child" scenario, who

have 59% (*SE* = 0.04, 95% CI [0.50, 0.68]) probability in the control group and 71% (*SE* = 0.04, 95% CI [0.64, 0.79]) probability in the treatment group to display positive contingency; this difference is significant with $\chi^2(1) = 4.63$ ($p = .032$).

When looking at the measure of *Negative (or Lack of) Contingency* in Table 7, the results are slightly different. For the scenario "Both", we still see significant intervention effects, with the control group having a 5% (*SE* = 0.01, 95% CI [0.03, 0.07]) probability and the treatment group having a 2% probability (*SE* = 0.01, 95% CI [0.01, 0.03]) to show negative (or lack of) contingency in the present period; this difference is significant with $\chi^2(1) = 5.74$ ($p = .017$). No significant differences are detected for the boys and their mothers. For the "None" scenario, there is a significant difference for both girls' and boys' mothers, with 13% (*SE* = 0.08, 95% CI [-0.03, 0.28]) and 10% (*SE* = 0.10, 95% CI [-0.08, 0.29]) probabilities for those in the control group, and 47% (*SE* = 0.08, 95% CI [0.30, 0.63]) and 57% (*SE* = 0.25, 95% CI [0.09, 1.05]) probabilities for those in the treatment group respectively; both being significant ($\chi^2(1) = 8.33$, $p = .004$ and $\chi^2(1) = 3.17$, $p = .075$). In the "Child" scenario, no significant difference is detected for any of the groups. In the "Mother" scenario, there is a significant difference for girls, with the control group having 15% (*SE* = 0.04, 95% CI [0.08, 0.22]) probability and the treatment group having only 6% (*SE* = 0.03, 95% CI [0.00, 0.12]) probability of showing negative or lack of contingency; this difference is significant, with $\chi^2(1) = 3.93$ ($p = .047$). In addition, marginally significant differences are found for the boys, with positive effects for the children (27% (*SE* = 0.02, 95% CI [0.21, 0.33]) probability in the control group and 15% (*SE* = 0.06, 95% CI [0.03, 0.26]) in the treatment group), and negative ones for their mothers (1% (*SE* = 0.01, 95% CI [0.00, 0.02]) and 9% (*SE* = 0.04, 95% CI [0.00, 0.17]) in the control and treatment group respectively); both differences are statistically significant ($\chi^2(1) = 3.82$, $p = .051$ and $\chi^2(1) = 3.05$, $p = .081$ respectively).

Discussion

The present study is distinctive in that it uses a sequential micro coding system for mother-child interactions in a randomized experiment of a home visiting program. The program focused on

disadvantaged first-time mothers, started during pregnancy, and continued up until the second birthday of the child. To study mother-child interactions, we performed both a more traditional static analysis and a novel dynamic analysis, considering behavioral actions and reactions of both, mother and child, by means of cross-lagged models. We focused on three key behaviors of interest: *Orientation, Positive Contingency*, and *Negative or Lack of Contingency* of the mother and the child.

In summary, one main finding emerges from the static analysis. While the program shows only limited effects on mother-child interactions in the whole sample, the analysis by gender reveals that the intervention improved the interactions between girls and their mothers, but not between boys and their mothers. However, the static analysis does not consider the behavioral responses to specific actions of either partner. For example, it does not shed light on whether the intervention improved the persistence of stable situations (mother and child show positive behaviour in the previous period), or also helped escaping unstable ones (mother and/or child show negative behaviour in the previous period). Therefore, the static analysis might hide important aspects of the workings of the intervention.

Several important findings emerge from the dynamic analysis. We report them by scenario ("Both", "None", "Mother" and "Child") and by gender. The first is that for all three behaviors of interest *(Orientation, Positive Contingency,* and *Negative or Lack of Contingency)* the intervention has a positive impact on the girls in the scenario "Both". In particular, the girls in the treatment group are more persistent in their positive behavior when compared to the girls in the control group, conditional on their mother also showing positive behavior in the previous period. These findings are important as situations in which mother and child show positive behaviour are more stable in treatment group than in the control group, thereby indicating higher stability in girls' interactions with the mothers as an outcome of the program. In line with the improvements seen for the treated girls' behavior in stable situations, we also find improvements for their mothers in the "Both" scenario for *Orientation.*

Second, we find that mothers of girls in the treatment group more often persist in *Negative or Lack of Contingency* if they showed this behavior in the previous period, i.e. in the "None" scenario.

However, this negative effect of the intervention for mothers of girls is limited to this scenario ("None") and behavior ("*Negative or Lack of Contingency*"). There are no significant effects in the "None" scenario for the other behaviors.

Third, for the scenario "Child", despite the mother not showing positive contingency in the previous period, girls in the treatment group did not stop showing *Positive Contingency.* This suggests that the treated girls are more stable and continue to display positive behavior, even if their mother is not acting positively. There are no significant effect in the "Child" scenario for the other behaviors.

Fourth, for the scenario "Mother", i.e. if the mother showed positive behavior in the previous period, the treated girls are more likely than the control girls to switch, and to show more *Orientation* and less *Lack of Contingency*. These results suggest that the girls in the treatment group respond to positive behavior of the mother more than the girls in the control group, switching from the negative behavior shown in the previous period. This finding may indicate a higher sensitivity of the mothers in the intervention group if their daughter show negative behavior.

While the intervention clearly improved the interactions between mothers and their daughters, the results for the son dyads are mixed. First, for the scenario "Both", both sons (for *Positive Contingency*) and their mothers (for *Orientation* and *Positive Contigency*) exhibit less stable behaviors. Second, as seen for daughters, we find that boys' mothers in the treatment group more often persist in *Negative or Lack of Contigency* in the "None" scenario, i.e. if themselves and their sons showed this behavior in the previous period. Third, for the "Mother" scenario we find mixed impacts for *Negative or Lack of Contigency* with positive effects for the sons (who switch to a more positive behavior) and negative effects for their mothers (who display less stable behavior), in the presence of positive maternal behavior in the previous period. All the other effects are not significantly different. Therefore, it appears that the treatment had mixed effects on the interactions between boys and their mothers.

Overall, the results from the dynamic analysis confirm the results from the static analysis: the intervention significantly improved the interactions between girls and their mothers. However, the

dynamic analysis substantially improves our understanding of the circumstances under which these improvements occurred. First, girls in the treatment group always display improved behavior in strongly stable situations (i.e. in the scenario "Both", where both the mother and the child displayed positive behavior in the previous period), in comparison to girls in the control group. This is showing that home visiting prevents unpredictable behavior changes and fosters stability in dyadic interactions.

Second, the girls in the treated group also showed improved behavior in less stable situations. In particular, they showed greater stability of *Positive Contingency*, even in the absence of a positive behavior of the mother in the previous period (scenario "Child"), and displayed greater ability to switch to more *Orientation* and less *Negative Contingency* in presence of the mother's positive behavior in the previous period (i.e. even in the absence of their own positive behavior in the previous period in the "Mother" scenario). This finding could be interpreted as showing that the interventions maintained positive behavior in face of adversity, and helped escaping negative behavior.

Hence, a main finding of the analysis is that the interaction between mothers and daughter appear to benefit more by the intervention than the interaction of mothers and sons. This is consistent with the early interventions literature cited previously showing greater impacts for girls, including previous evidence based on the *Pro Kind*. In the *Pro Kind* trial, in addition to biological explanations pointing to greater female susceptibility to early conditions and greater expected returns from interventions, other critical factors which might contribute to the emergence of impacts more favourable to girls are the absence of a father and the availability of limited resources, which have been associated with increased investment in girls (Gibson, 2008; Godoy et al., 2006).

Limitations

Despite its strength and novelty, the present study has some limitations. First, we have video recordings of only three minutes duration. Longer (or repeated) recordings could reveal more interactions and behavioral changes, in particular for behaviors that occur less frequently. Second, our analysis is based on a subsample of the original RCT. Although we show that our analysis sample is

comparable to the baseline sample under observable characteristics, unobservable characteristics may differ. Furthermore, because we rely on a subsample, the sample size is not as large as in the baseline sample. However, our analysis sample is still comparable to many other studies investigating the effects of home visiting programs by RCTs. Third, the lack of video recordings at more time points is a limitation of our study. The videos are only recorded when the child is 2 years of age. The study could have benefited from videos at different ages to analyse effects of the intervention on mother-child interactions at different stages of child development (as for example in Meins et al., 2018). Finally, the videos recorded only mother-child interactions. Therefore, we cannot say whether the home visits influenced father-child interactions.

Conclusions and Implications

Our study is the first to examine the effects of a home visiting program on parent-child interactions using microsocial measures and dynamic modelling. Most previous studies applied static analysis to global coding schemes, which do not fully capture the dynamics of the repeated interactions between mother and child. We have shown that it is important to consider these dynamic interactions to better understand the mechanisms through which home visiting generates effects and under which conditions certain types of mother-child interactions are most affected.

Our results show that the effects of the *Pro Kind* program are concentrated among girls and that girls in the treated group show more stable and positive interaction behavior than girls in the control group. Our findings and methodology might spur further research using video data to assess mother-child interactions in home visiting programs but also in other settings. Additionally, our findings might also influence the design and delivery of home visiting programs, because they show that more effort is needed to improve the interactions between boys and their mothers.

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Table 1: Sample characteristics

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variable	**Categories**	**C**	**T**	***p* val.**	**Female**	**Male**	***p* val.**	**Base. sample**	**Video sample**	***p* val.**
Group	Control				31	24	.780	306	55	.550
	Treatment				29	25		340	54	
Child's Gender	Female	31	29	.780				266	60	.696
	Male	24	25					236	49	
Mother's birthplace	Germany	44	49	.113	50	43	.516	562	93	.633
	Other	11	5		10	6		84	16	
State	Bremen	25	29	.389	30	25	.916	165	54	.000
	Lower Saxony	30	25		30	24		231	55	
Partner	Present	40	36	.491	39	37	.235	442	76	.702
	Not Present	15	18		21	12		184	33	
Add. persons in HH	0	13	10	.578	14	9	.416	145	23	.922
	1	19	24		19	24		243	43	
	2+	17	15		17	15		192	32	
School/ Qualification	Degree	41	40	.955	42	39	.254	496	81	
	No Degree	14	14		18	10		144	28	.464
Occupational level	Unemployed	50	42	.059	51	41	.849	540	92	.966
	Employed	5	12		9	8		101	17	
Mother's Age (mean)		21.70	21.65	.480	21.55	21.83	.746	21.35	21.68	.466
Household income (mean)		933.35	1,123.83	.093	976,99	1.079,57	.369	910.54	1,025.58	.052

Notes: Columns (3), (6) and (9) report p-values of tests for the equality of means of selected characteristics between treated and controls in the video sample, between males and females in the video sample, and between the full baseline and the video sample, respectively. C = Control group, T = Treatment Group

Table 2: Correlation with Observable characteristics

	Overall	Girls	Boys	Wald Test	
		Child Orientation			
Low BW	-27.76*	-40.88***	14.11	1.81	$p = .182$
	(14.83)	(13.90)	(43.30)		
Cognitive 24m	0.62*	0.22	0.95*	1.36	$p = .246$
	(0.31)	(0.39)	(0.50)		
		Child Contingency Positive			
Low BW	9.49	0.76	30.11	0.76	$p = .384$
	(12.16)	(11.98)	(34.13)		
Cognitive 24m	-0.08	-0.27	-0.04	0.17	$p = .683$
	(0.27)	(0.34)	(0.44)		
		Child Contingency Negative-Lack			
Low BW	8.93*	7.00	29.00*	2.67	$p = .106$
	(4.89)	(4.46)	(14.52)		
Cognitive 24m	-0.25**	-0.20	-0.25	0.05	$p = .827$
	(0.11)	(0.12)	(0.20)		
		Mother Orientation			
Risk Depress	-25.88***	9.65	-32.68**	3.91	$p = .051$
	(9.41)	(16.45)	(12.27)		
		Mother Contingency Positive			
Risk Depress	-17.75*	11.05	-22.47**	2.47	$p = .119$
	(9.30)	(18.13)	(11.08)		
		Mother Contingency Negative-Lack			
Risk Depress	6.90	7.72	7.18	0.09	$p = .769$
	(5.52)	(9.11)	(7.95)		

*Notes: Risk Depress is a binary variable which is 1 if the mother shows symptoms of depression, measured by the Depression Anxiety Stress Scale (DASS). Cognitive Development is measured by the Bayley Scales of Infant Development II (BSID-II). Low BW is a binary variable which is 1 if the birth weight was < 2500g. Wald Test p-values are for the equality of coefficients between male and female samples. *** p<0.01, ** p<0.05, * p<0.1.*

Table 3: Description of Scenarios for Treatment Effects Analysis

		Behavior in current period:		
		(1) Orientation on Partner and Play Situation	(2) Contingency Positive	(3) Contingency Negative + Lack
Scenario Name				
Both	Child	1	1	0
	Mother	1	1	0
None	Child	0	0	1
	Mother	0	0	1
Child	Child	1	1	0
	Mother	0	0	1
Mother	Child	0	0	1
	Mother	1	1	0

*Note: The name of the scenario is based on the behavior of the mother and the child in the **previous** period. For example, in the scenario "Both" in column 1, both mother and child show "Orientation on Partner and Play Situation" (indicated by 1) in the **previous** period. In the scenario "None" in column 2, neither mother or child show "Contingency Positive" (indicated by 0) in the previous period.*

Table 4: Treatment Effects on Outcomes (Probit and OLS)

	Probit (AME)				OLS (Secs)			
	All	**Girls**	**Boys**	**Wald**	**All**	**Girls**	**Boys**	**Wald**
	Child Orientation on play situation and mother							
Treat	0.04	0.15***	-0.09	9.47***	6.83	26.77***	-16.72	9.56***
	(0.04)	(0.04)	(0.06)	p = .002	(7.33)	(8.11)	(11.75)	p = .003
R^2					0.01	0.16	0.04	
C. Mean	0.49	0.48	0.52		88.82	85.65	92.92	
	Child Contingency Positive							
Treat	0.00	0.06	-0.07	3.63*	-0.41	9.99	-12.23	3.62*
	(0.03)	(0.04)	(0.05)	p = .057	(6.00)	(7.03)	(9.53)	p = .060
R^2					0.00	0.03	0.03	
C. Mean	0.57	0.58	0.56		103.00	104.84	100.63	
	Child Contingency Negative-Lack							
Treat	-0.04***	-0.034**	-0.04	0.075	-6.25***	-5.98**	-6.79	0.03
	(0.01)	(0.02)	(0.02)	p = .785	(2.32)	(2.54)	(4.13)	p = .865
R^2					0.06	0.08	0.06	
C. Mean	0.07	0.06	0.08		12.55	10.81	14.79	
	Mother Orientation on play situation and child							
Treat	-0.02	0.04	-0.09	3.10*	-4.15	6.40	-16.15	3.31*
	(0.04)	(0.04)	(0.06)	p = .079	(6.31)	(7.19)	(10.32)	p = .073
R^2					0.00	0.01	0.05	
C. Mean	0.81	0.82	0.80		146.00	147.74	143.75	
	Mother Contingency Positive							
Treat	-0.02	0.02	-0.07	1.58	-3.73	3.53	-11.82	1.64
	(0.03)	(0.04)	(0.05)	p = .209	(6.11)	(7.91)	(9.21)	p = .203
R^2					0.00	0.00	0.03	
C. Mean	0.66	0.67	0.64		118.64	121.13	115.42	
	Mother Contingency Negative-Lack							
Treat	0.01	0.01	0.01	0.00	0.09	0.17	-0.01	0.00
	(0.02)	(0.02)	(0.04)	p = .975	(0.16)	(0.17)	(0.29)	p = .974
R^2					0.00	0.02	0.00	
C. Mean	0.05	0.05	0.05		8.73	8.71	8.75	
Obs.	3,924	2,160	1,764		109	60	49	

*Notes: Clustered Standard Errors in parentheses. In the Wald column we report t-statistics and their associated p-values. *** p<0.01, ** p<0.05, * p<0.1. C. Mean = Control Mean, AME=Average Marginal Effect, Secs=seconds.*

Table 5: Predicted Probabilities - Different Scenarios – **Orientation**

Scenario		Both			None		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.67	0.76	4.07**	0.24	0.32	2.11
(N=2,100)		(0.04)	(0.02)	p = .044	(0.04)	(0.04)	p = .147
	Mother	0.92	0.95	2.93*	0.47	0.40	1.17
		(0.01)	(0.01)	p = .087	(0.04)	(0.05)	p = .280
Boys	Child	0.74	0.67	1.19	0.19	0.19	0.00
(N=1,715)		(0.03)	(0.05)	p = .276	(0.05)	(0.04)	p = .993
	Mother	0.94	0.87	3.68*	0.40	0.40	0.00
		(0.02)	(0.03)	p = .055	(0.06)	(0.04)	p = .976

Scenario		Child			Mother		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.56	0.61	0.59	0.34	0.48	9.83***
(N=2,100)		(0.06)	(0.04)	p = .441	(0.03)	(0.04)	p = .002
	Mother	0.59	0.59	0.00	0.87	0.88	0.27
		(0.06)	(0.06)	p = .992	(0.02)	(0.02)	p = .602
Boys	Child	0.55	0.52	0.10	0.36	0.31	0.84
(N=1,715)		(0.07)	(0.07)	p = .750	(0.03)	(0.04)	p = .359
	Mother	0.60	0.53	0.49	0.84	0.79	1.26
		(0.08)	(0.07)	p = .483	(0.03)	(0.04)	p = .261

*Notes: The coefficients show the probability of orientation on the play situation for each partner in each of the different scenarios described in Table 2. C = Control Group, T = Treatment Group; *** p<0.01, ** p<0.05, * p<0.1.*

Table 6: Predicted Probabilities - Different Scenarios - **Contingency Positive**

Scenario		Both			None		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.65	0.73	5.47**	0.48	0.48	0.00
(N=2,100)		(0.03)	(0.02)	p = .019	(0.04)	(0.05)	p = .974
	Mother	0.74	0.77	0.40	0.53	0.53	0.00
		(0.03)	(0.02)	p = .528	(0.04)	(0.04)	p = .982
Boys	Child	0.71	0.59	4.66**	0.36	0.40	0.31
(N=1,715)		(0.03)	(0.04)	p = .031	(0.05)	(0.04)	p = .576
	Mother	0.78	0.65	6.00**	0.43	0.47	0.58
		(0.04)	(0.04)	p = .014	(0.05)	(0.04)	p = .447

Scenario		Child			Mother		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.59	0.71	4.63**	0.54	0.50	0.66
(N=2,100)		(0.04)	(0.04)	p = .032	(0.03)	(0.03)	p = .417
	Mother	0.63	0.57	1.13	0.66	0.74	2.37
		(0.04)	(0.04)	p = .287	(0.04)	(0.04)	p = .124
Boys	Child	0.64	0.57	1.68	0.43	0.42	0.03
(N=1,715)		(0.04)	(0.05)	p = .195	(0.05)	(0.04)	p = .852
	Mother	0.57	0.51	0.82	0.66	0.61	0.51
		(0.06)	(0.04)	p = .364	(0.05)	(0.03)	p = .473

*Notes: The coefficients show the probability of positive contingency for each partner in each of the different scenarios described in Table 2. C = Control Group, T = Treatment Group; *** p<0.01, ** p<0.05, * p<0.1.*

Table 7: Predicted Probabilities - Different Scenarios - **Contingency Negative-Lack**

Scenario		Both			None		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.05	0.02	5.74**	0.17	0.14	0.12
(N=2,100)		(0.01)	(0.01)	p = .017	(0.06)	(0.07)	p = .733
	Mother	0.05	0.04	0.09	0.13	0.47	8.33***
		(0.01)	(0.01)	p = .760	(0.08)	(0.08)	p = .004
Boys	Child	0.07	0.04	2.22	0.27	0.31	0.13
(N=1,715)		(0.02)	(0.01)	p = .136	(0.10)	(0.06)	p = .717
	Mother	0.04	0.03	0.34	0.10	0.57	3.17*
		(0.01)	(0.01)	p = .562	(0.10)	(0.25)	p = .075

Scenario		Child			Mother		
		C	T	Wald Test	C	T	Wald Test
Girls	Child	0.06	0.07	0.02	0.15	0.06	3.93**
(N=2,100)		(0.03)	(0.03)	p = .892	(0.04)	(0.03)	p = .047
	Mother	0.15	0.29	2.16	0.03	0.10	1.94
		(0.05)	(0.08)	p = .141	(0.02)	(0.04)	p = .164
Boys	Child	0.06	0.11	0.61	0.27	0.15	3.82*
(N=1,715)		(0.03)	(0.04)	p = .435	(0.03)	(0.06)	p = .051
	Mother	0.27	0.38	0.27	0.01	0.09	3.05*
		(0.11)	(0.18)	p = .607	(0.01)	(0.04)	p = .081

*Notes: The coefficients show the probability of negative contingency or lack of contingency for each partner in each of the different scenarios described in Table 2. C = Control Group, T = Treatment Group; *** p<0.01, ** p<0.05, * p<0.1*