The effects of home visiting on mother-child interactions:

Evidence from a randomized trial using dynamic micro-level data

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[Accepted Version]

Published in Child Abuse & Neglect: https://doi.org/10.1016/j.chiabu.2021.105021

Funding: Gabriella Conti and Malte Sandner have received funding from the Nuffield Foundation (grant No. EDO/43715). Gabriella Conti and Stavros Poupakis have received funding from the European Union's Horizon 2020 research and innovation programme (grant agreement No. 633595 DynaHEALTH). Gabriella Conti thanks for support the European Research Council under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 819752 DEVORHBIOSHIP – ERC-2018-COG).

Acknowledgment: We thank Mirjam Otten for outstanding research assistance in the revision of this paper. We also thank Isabelle Deterding and Verena Dähne for their fieldwork support, and Patricia Trautmann-Villalba for the training of the coders in the Mannheim rating scale.

Abstract

Background: Home visiting programs constitute an important policy to support vulnerable families with young children. One of their principal aims is to improve infant-parent relationships, so a key measure of their effectiveness is based on observational measures of parent-children interactions. In the present study we provide novel evidence on the effectiveness of home visiting programs in improving mother-child interactions within a randomized controlled trial (RCT) of the *Pro Kind* program. A major goal of the Pro Kind program is to promote child development by strengthening the intuitive parenting skills of mothers. On this basis, the following research question is addressed in this paper: What is the impact of the Pro Kind home visitation program on the quality of mother-child interaction?

Methods: A randomly chosen subsample of the original sample was selected to participate on video recordings. This subsample of 109 mother-child dyads was videotaped during a 3-min typical play situation at the participants' homes when the child was aged 25 months. We use a novel micro-coding system which allows us to examine how the intervention affected the dynamic feedback responses of both mothers and children in three key measures of behavior: orientation, positive contingency, and negative/lack of contingency. The analysis was conducted using a set of static probit models and dynamic cross-lagged panel probit models for each measure.

Results: The intervention significantly improved the interactions between girls and their mothers, by increasing the prevalence of orientation and positive contingency (and reducing that of negative/lack of contingency). This was achieved by increasing both the persistence of positive behaviors and also the probability of switching from negative to positive behaviors in the treatment group. Mixed impacts were detected for boys.

Conclusions: Overall, it can be said that the Pro Kind program has a positive impact on the quality of mother-daughter interaction. However, our findings might also influence the design and delivery of home visiting programs, to the extent that they suggest that more attention has to be devoted to the interactions between boys and their mothers. Furthermore, the results show the importance of careful dynamic modelling of interactions data from videotaped observations to have a more complete understanding of the effectiveness of home visiting programs.

Keywords: Home Visiting; Mother-child Interactions; Randomized Controlled Trial; Micro-coding System.

Introduction

Early experiences can have a lasting impact on life course well-being. Children born in vulnerable families risk failing to reach their developmental potential, in part because they are exposed to unstable, unsafe and non-stimulating environments (e.g., Bradley, et al., 2001). In many countries home visiting programs constitute an important strategy to support vulnerable families with young children, and several studies show their effectiveness at promoting child development (for reviews see Sweet & Appelbaum, 2004; Avellar & Supplee, 2013; Olds et al., 2007; Michalopoulos et al., 2019). Almost all home visiting programs aim to improve the relationship between infants and parents, support sensitive parenting and reduce the likelihood of child abuse and neglect (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). On the other hand, different reviews have identified impairment of maternal responsiveness as a consistent feature of maltreatment offenders (Milner & Chilamkurti, 1999; Milner & Dopke, 1997; Stith et al., 2009). Furthermore, studies show that physically abusive mothers speak and interact less with their children in laboratory situations (Conron, et al., 2009; Kluczniok et al., 2016).

The relationship between mother-child interaction and child abuse appears to be of great importance in the evaluation of home visiting programs. For example, direct observation of such behaviors is hampered by the fact that frequent contact with home visitors makes it more likely that child abuse or neglect will be detected in families in the intervention group, while it may go unnoticed in families in the control group (Howard & Brooks-Gunn, 2009). In contrast, direct interviews with parents (e.g., by means of questionnaire procedures) can be distorted by processes of social desirability, whereby direct interviews with children in younger age groups are generally not feasible. Accordingly, proxy measures such as children's health (e.g., number of injuries and visits to the emergency room) as well as objective behavioral observations of parent-child interaction in standardized observation situations seem a promising way to gain insight into the effectiveness of home visiting programs targeting indicators of maladaptive parenting and child abuse especially in younger age groups.

Aim of the Study

We use a novel dynamic feedback analysis of mother-child interactions within an objective micro-coded system to examine the effectiveness of the home visiting program *Pro Kind.* This program 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). A major goal of the Pro Kind program is to promote child development by strengthening the intuitive parenting skills of mothers. Based on this, we hypothesize that the Pro Kind program would, in comparison to a control group: (1) increase the occurrence of positive behaviors in mothers and children; (2) increase differently the occurrence of positive behaviors between mother-daughter and mother-boys pairs; (3) improve differently the mother-child interactions between mother-daughter and mother-boys pairs.

Observational measurements of parent-child interactions have already been examined in other home visit programs. For example, in an NFP trial Olds et al. (2004) found that mother-child dyads showed more sensitive and reactive interactions during a free play situation in intervention group dyads compared to control group dyads. Furthermore, effectiveness studies of the home visiting program *Early Head Start* (EHS; Love et al., 2005) as well as *Healthy Families New York* (HFNY; Rodriguez et al., 2010) reported both positive treatment effects on parent-child interaction. However, certain limitations must be mentioned for these studies. For example, two of these studies (Love et al., 2005; Olds et al., 2004) use only a global score for one entire video session (known as "global coding system"). In the third study (Rodriguez et al., 2010) the authors simply counted the frequencies of certain behaviors (HFNY). Additionally, in all three studies the coding was based on mothers' initial behavior while the initial behavior of the child was not considered.

However, the importance of observing full sequences to study the mutuality of mother-child interactions has been emphasized since Tronick et al. (1977). It has also been shown since Markman & Notarius (1987) and Floyd (1989) in the context of couple relationships that only micro-coding systems can reveal complex patterns of interactions considering dynamic reactions of *both* members of a dyad. For example, Bardack et al. (2017) proved that micro-coded measures of mother-child interactions independently predict fewer externalizing and inattentive/impulsive behaviors in school, whereas global-coded measures do not. A particularly useful reference is the widely-cited piece by Chorney and Gorodzinsky (2017), who discuss the characteristics of different coding methodologies, and note that "In comparison to global ratings, systematic behavioral coding captures more precise information on the nature of the behaviors being observed". Along the same lines, Dishion et al. (2017) apply both macro and micro coding schemes to parent-child interactions at an early age, and find that macro-coding techniques are lacking in refinement and unable to show nuanced dimensions in complex parent-child interactions.

On the other hand, other studies provide more balanced accounts of the benefits and limitations of both global and micro-coding schemes. Chorney et al. (2015) discuss both strengths and weaknesses of macro- and micro-coding, highlighting that the method of choice is contingent to the research question and the population of interest; in particular, they suggest that a process-focused evaluation (like the one we carry out in this paper) would benefit from higher granularity in the coding process, whilst macro-coding is more tailored to outcome-oriented research. Pesch and Lumeng (2017) and Tschan et al. (2018) also notice that a particular coding scheme needs to be chosen taking into account the hypothesis at hand. In relation to maternal behavior, Mesman (2010) advocates an inclusive use of both approaches, noting that, whilst micro-coding describes maternal contingency in terms of intuitive parenting, macro-coding captures maternal responsiveness based on planned parenting.

Still, micro-coding schemes have not been used to date when evaluating the effects of home visiting programs. In this paper, we overcome the limitations of previous home visiting effectiveness studies which only used global measures of mother-child interactions, or static micro measures that simply counted frequencies and only focused on mothers. Therefore, these studies may miss important effects of the interventions on mother-child interactions, which may be important in context of child maltreatment prevention. We also improve on previous studies (Beebe et al., 2009,2016) which used dynamic modelling, by applying it for the first time to a randomized trial, and also by jointly modelling the dynamic responses of each member of the dyad and by allowing them to vary by the initial behavior of each member. In this way, we can also examine whether the effectiveness of the intervention varies depending on the starting behavior of each member of the dyad. In consideration of the fact that in other studies on NFP (e.g. Arcoleo et al., 2010; Eckenrode et al., 2010; Lorber et al., 2019) gender effects were found, we will conduct our analysis separately for boys and girls.

Methods

Intervention

The *Pro Kind* is an adaptation of the NFP program. As in the NFP, the intervention starts between the 12th and 28th week of pregnancy, and continues until the child's second birthday. The frequency of the home visits varies between weekly, biweekly, and monthly according to the NFP model, for an overall maximum of 52 home visits with an average duration of 90 minutes each. Teaching materials and visit-by-visit guidelines, adapted from NFP, structure the aim and content of each home visit. 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 self-efficacy (Bandura, 1982). In contrast to NFP, where nurses conducted the home visits, in Pro Kind mainly family midwives and social pedagogues conducted the home visits alone or in a team. However, in Germany family midwives and social pedagogues are professions with similar qualification as nurses. Specifically, both family midwives and nurses hold a three-year apprenticeship degree consisting of 1,600 hours of theory and 3,000 hours of practical training, while social pedagogues hold a university BA degree. Kliem et al. (2018) and Olds (2006) present more information about the *Pro Kind* project and NFP, respectively.

Participants and procedure

The *Pro Kind* trial enrolled N = 755 expectant women in three federal states of Germany (Lower Saxony, Bremen and Saxony); all of them were financially and socially disadvantaged with at least a basic understanding of the German language. 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, n = 346 of the mothers participated in a follow-up interview (see CONSORT flow diagram in figure 1). At this follow-up, videotapes were recorded in Lower Saxony and Bremen for n = 150 randomly chosen mother-child pairs (it was not possible to record them for the full sample for budgetary reasons); of these, n = 41 videos were not coded because they were shorter than three minutes, leaving an analysis sample of n = 109 mother-child pairs with coded videos. Table 1 shows that the video subsample is balanced, with no differences in observed baseline characteristics significant at 5% level between the treated and the control group (Columns 1-3), as well as between girls and boys (Columns 4-6). The women in our video subsample are also not significantly different from those in the full sample, with the exception of having higher income (Columns 7-9). This is the case also for children, who are not significantly different in terms of birthweight. 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. Similarly to the full sample, the mothers in our video subsample received M = 46.79 (SD = 8.92, range: 13-63) home visits on average. In addition, a post-hoc power analysis using G*Power with an alpha level of 0.05 and a sample of 109 participants revealed that there is adequate power (>80%) to detect moderate effect sizes (Cohen, 1988). For the stratified analysis, the power for moderate effect sizes was slightly smaller (>74%) using the same alpha level and the split sample.

Measures

To measure interactions, the mothers were asked to play for three minutes with the children in their homes, without performing any specific task. Video recording was done by female research assistants (studying psychology or special needs education) who received standardized training and ongoing supervision in interviewing techniques and developmental testing from the research staff.

Two persons independently 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), which has been used in other published studies (Trautmann-Villalba et al., 2006; Hohm et al., 2017). 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 to .87). The software *Interact*, a computer-based video analysis tool was used for video ratings. Both the research assistants and the coders were blind to the treatment condition of the dyads.

For our analysis of mother child-interactions, we focused on the MRS-MCI-T scales *Orientation* and *Contingency*, which have been related to the quality of attachment, especially in Germany (Grossman et al., 1985; Scher, 2001); the importance of contingency for the development of attachment has also been shown in Beebe et al. (2010, 2016) and Landry et al. (2012). The coders rated the scales one after another separately for mother and child, for all 109 videos, following the recommended order of the MRS-MCI-T guidelines. Coder A rated 78 videos and coder B rated 31 videos.

The coding interval for *Orientation* is 5 seconds, in which the main attention focus of the subject 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 if the orientation was on the play situation and the partner (a positive behavior), and as 0 if it was on neither one of the two. The coding interval for *Contingency* – whose aim is to measure the reciprocity of the interaction - is also 5 seconds, in which all direct and distinct reactions (positive, negative, initiation of interaction and also lack of reaction) to the partner's behavior were observed. We generated two separate binary variables coded in 5 second intervals. These variables are mutually exclusive. The first takes value 1 if the child or the mother showed *Positive Contingency* (e.g. if the child smiled at the mother), including initiation of interaction, and 0 if otherwise; the second takes value 1 if the child or the mother showed *Negative or Lack of Contingency (*e.g. if the child reacts crying to an action of the mother or if the mother does not react to an action of the child), and 0 if otherwise. As such, there are cases where for a specific 5-second interval, both of these variables take the value of 0. These are cases in which neither the mother nor the child showed any interaction (e.g. both are playing with the toy but they are not interacting with each other).

These behaviors are meaningful indicators as they are correlated with important risk factors. Table 2 presents the associations of the behaviors with low birth weight, cognitive development at 24 months (as measured by the Bayley Scales), and depression. In order to perform this analysis, we aggregate all the behaviors by taking the sum of seconds each behavior was observed during the 3-minute recording. The results show that child and mother Orientation and Positive (Negative/Lack) Contingency correlate negatively (positively) with low birth weight and depression, respectively. Additionally, child Orientation and Negative/Lack Contingency correlate positively and negatively, respectively, with cognitive development at 24 months (as measured by the Bayley Scales), while a self-rated parenting scale (Arnold et al., 1993) does not.

Interaction scenarios

To test the dynamic interdependency of mother-child actions, we focus on four scenarios in which we investigate how one partner in each period reacts to the corresponding behavior (*Orientation, Positive Contingency, Negative or Lack of Contingency*) of the other in the previous period. The first scenario (*"Both"*) represents a strongly stable situation, in which we examine how the child or the mother reacts if *both* partners showed *positive* behavior in the previous period. The second scenario (*"None"*) 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 (*"Child"* and "*Mother"*) 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. Figure 2 gives an overview of these scenarios where each column indicates the mother's and child's behavior, in the previous period, for each of the four hypothetical scenarios.

The first scenario is interesting because, when 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 the intervention is able to induce positive behavior in a stressful situation, where both partners show negative behavior. The last two scenarios 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, 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.

Statistical Analysis

To demonstrate the usefulness of our dynamic modeling approach, we start with a simpler, “static” analysis, in which, for each mother-child pair i at time point t, the binary outcome y_{it} takes value 1 if a certain behavior is present in that interval. Thus, for the following 6 outcomes: Orientation, Contingency Positive and Contingency Negative-Lack (for child and mother separately) we use the following Probit model (with clustered Standard Errors to account for repeated observations over time):

$$\Pr(y_{i,t} = 1|Treat_i) = \Phi\left(\beta_0 + \beta_1 Treat_i\right)$$

As the estimated coefficients in Probit models are hard to interpret, we report the Average Marginal Effects (AMEs). Since the variable $Treat$ is binary, the AME has the form:

$$\frac{1}{n}\sum_{i=1}^{n}\left\{\Phi\left(\hat{y}_i \middle| Treat_i = 1\right) - \Phi\left(\hat{y}_i \middle| Treat_i = 0\right)\right\}.$$

We then perform a novel *dynamic interaction analysis,* in which we simultaneously model two equations with correlated errors - one for the mother and one for the child - for each of the three behaviors *(Orientation*, *Positive Contingency*, *Negative or Lack of Contingency*), as function of the behavior of both members of the dyad in the previous period, by means of cross-lagged panel probit models. The previous work more similar to ours is Beebe et al. (2009,2016), who videotaped an urban community sample of 84 dyads (at 4 months during a face-to-face interaction, and at 12 months during the Ainsworth Strange Situation), and used contingency measures (multi-level time-series modelling) to examine the dyadic temporal processes over time. We innovate on the individual growth models of Beebe et al. (2009,2016), by modelling simultaneously mother and child behaviors, allowing for correlations in the errors of the two equations (one for each member of the dyad). We include as covariates in each equation: the first lag of the mother’s and the child’s outcome, a binary variable for treatment status and its interactions with the two lags (to allow for the effect of the intervention to vary with the behavior of the partner in the previous period).

For the dynamic analysis, we model the same 6 outcomes as for the static analysis, using the following cross-lagged panel Probit models:

$$\Pr(y^C_{i,t}) = \Phi\left(\beta^C_0 + \beta^C_1 Treat_i + \beta^C_2 y^C_{i,t-1} + \beta^C_3 Treat_i * y^C_{i,t-1} + \beta^C_4 y^M_{i,t-1} + \beta^C_5 Treat_i * y^M_{i,t-1}\right)$$

$$\Pr(y^M_{i,t}) = \Phi\left(\beta^M_0 + \beta^M_1 Treat_i + \beta^M_2 y^M_{i,t-1} + \beta^M_3 Treat_i * y^M_{i,t-1} + \beta^M_4 y^C_{i,t-1} + \beta^M_5 Treat_i * y^C_{i,t-1}\right)$$

Where $y^C_{i,t}$ is the outcome for the child and $y^M_{i,t}$ is the outcome for the mother, and similarly are defined all the other covariates in the model with the superscripts C and M. These two equations are estimated together, by assuming jointly normal error terms (ϵ^C_t and ϵ^M_t) across them as follows

$$\begin{pmatrix}\epsilon^C_t \\ \epsilon^M_t\end{pmatrix}\Bigg| X^C, X^M \sim N\left(\begin{matrix}0\\0'\end{matrix}\begin{bmatrix}1 & \rho \\ \rho & 1\end{bmatrix}\right)$$

where the non-zero correlation ρ allows the two equations to be correlated through their error terms. The Marginal Effects are calculated in the same way as for the static case, and the values for the conditional variables (i.e. the behaviors in t-1) are assigned depending on the different scenarios displayed in Figure 2. The equality of the coefficients in the male and female models (reported in Tables 2, 3 and 4) is tested using the Wald test.

Results

We first report the results for the static analysis for which we show the Average Marginal Effects in Table 3 and are based on the first two hypotheses. Contrary to the first hypothesis, there are no differences in the occurrence of a positive behavior between the treatment and control group for most measures, apart from a decrease in child's negative or lack of contingency. Our second hypothesis gives mixed evidence when we examine the average marginal effects for mother-daughter and mother-boy pairs separately. We find that the girls in the treatment group were 15 p.p. more likely to show orientation towards the task and the partner and 3.4 p.p. less likely to show negative or lack of contingency (i.e. almost half as likely as those in the control group), while the average marginal effects for boys and their mothers are negative but not significant. For the rest of the outcomes, mother-daughter and mother-boy pairs have average marginal effects of opposite sign, but they are not significant.

This leads us to our third, and main, hypothesis. We examine this using the results for the dynamic analysis, which are shown in terms of predicted probabilities for each of the different behaviors (*Orientation*, *Positive Contingency*, *Negative/Lack of Contingency*), separately by gender, for both the mother and the child, and for each initial behavior. In Table 4, there are four panels for each scenario. In each panel, the first and second columns show the predicted probabilities 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 scenarios are displayed for girls and boys, separately for children and mothers. We are interested in examining whether the Pro Kind programme improved the prevalence of positive behaviors or reduced the prevalence of negative behaviors, and if so, for whom and under which scenario.

Orientation

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 67% probability to be oriented towards the task and the mother in the current interval, whereas the girls in the treatment group have a significantly higher 76% probability. However, for their mothers, the respective probabilities of 95% and 92% for the treatment and control group we not significantly different.

For the scenarios "None" and "Child", there are no significant differences. Instead, in the "Mother" scenario, the control girls have 34% probability and the treated girls a significantly higher 48% probability to be oriented towards the task and the partner when the mother showed positive behavior (and the child herself negative behavior) in the previous period. In contrast, there are no positive impacts for the treated boys and their mothers.

Positive contingency

Under the scenario "Both", girls in the control group have 65% probability of showing positive contingency in the present period, whereas girls in the treatment group have a significantly higher probability of 73%; for mothers we detect no significant differences. In contrast, the treatment has a significantly negative impact on the boys and their mothers. There are no significant differences in the scenarios "None" and "Mother".

Instead, in the "Child" scenario, control girls have 59% probability and treated girls a significantly higher 71% probability to display positive contingency – even with their mothers showing negative behavior in the previous period.

***Negative contingency*.**

We see significant intervention effects in the scenario "Both" (where both displayed no negative behavior in the previous interval, see Figure 2), with the control group having a 5% probability and the treatment group having a 2% probability to show negative (or lack of) contingency in the present period. No significant differences are detected for the boys and their mothers. For the "None" scenario (where both mother and child displayed negative or lack of contingency in the previous interval), there is a significant difference for both girls' and boys' mothers, with 13% and 10% probabilities to remain in negative (or lack) contingency for those in the control group and 47% and 57% probabilities for those in the treatment group, respectively.

In the "Child" scenario, no significant difference is detected for any of the groups. In the "Mother" scenario (mother showed no negative (or lack of) contingency in the previous period), there is a significant difference for girls, with the control group having 15% probability and the treatment group having only 6% probability of showing negative or lack of contingency in the current interval; there is no significant difference for the boys.

Discussion

The present study uses a sequential micro-coding system to study mother-child interactions in a randomized experiment of a home visiting program. We performed a novel dynamic analysis, considering behavioral actions and reactions of both mother and child, by means of cross-lagged panel probit models. We focused on three key behaviors of interest for each partner: *Orientation, Positive Contingency,* and *Negative or Lack of Contingency*.

The static analysis, in which the effects of the intervention do not depend on the behavior of the dyad in the previous period, shows limited results, with increases in the probability of showing orientation towards the partner and task, and decreases in the probability of negative or lack of contingency, both for the girls in the treated group only. In practice, this simpler analysis hides more nuanced impacts of the intervention, which are only uncovered by accounting for the initial behavior of the dyad, which is done in the dynamic modeling.

The dynamic analysis, then, shows a much more informative picture. First, 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”. These findings indicate that the intervention fostered higher stability in girls’ interactions with their mothers, in the presence of positive initial behaviors. In line with the improvements seen for the treated girls in stable situations, we also find improvements for the mothers in the “Both” scenario for *Orientation.* Hence, the intervention increases the persistency of positive behavior. Second, in the scenario “Child”, girls in the treatment group are more likely to show *Positive Contingency,* despite the mother not showing it in the previous period. This suggests that the treated girls are more stable and continue to display positive behavior in face of an unfavorable environment, i.e. even if their mothers are not acting positively. Third, in the scenario “Mother”, the treated girls are more likely than the control girls to switch from negative to positive behavior, and to show more *Orientation* and less *Lack of Contingency*. These results suggest that the girls in the treatment group are more likely to respond to the positive behavior of their mother than the girls in the control group. This finding may indicate a greater sensitivity of the mothers in the intervention group who are better able to react if their daughters show negative behavior. However, while the intervention clearly improved the behaviors of the daughters, it seemed to have mixed effects on the interactions between boys and their mothers.

Overall, the dynamic analysis substantially improves our understanding of the situations in which the treatment improved mother-child interactions. First, treated girls always display improved behavior in strongly stable situations (i.e. in the scenario “Both”), in comparison to control girls: this shows that home visiting prevents unpredictable behavior changes and fosters stability in dyadic interactions. Second, treated girls also show improved behavior in less stable situations, i.e. they are able to show positive behavior even in the presence of negative behavior of themselves or their mothers in the previous period. This finding could be interpreted as showing that the intervention promotes resilience in face of adversity.

This finding that the intervention appears to benefit more the interactions between mothers and daughters than those between mothers and sons is consistent with the early interventions literature including previous NFP studies (Arcoleo et al., 2010; Eckenrode et al., 2010; Lorber et al., 2019) as well as findings on the *Pro Kind* study which show greater treatment impacts for girls (Sierau et al., 2016; Sandner, 2018). While we cannot provide a definite explanation for these gender differences, critical factors which might contribute to the emergence of impacts more favorable to girls in the *Pro Kind* trial include 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).

Furthermore, analyses of the interaction between mothers and their two-year-old children in the Mannheim risk study showed that boys, compared to girls, overlook interaction offers directed at them more often and show less interactive play behavior overall, while mothers show less restrictive control behavior toward their daughters than toward their sons (Dinter-Jörg et al., 1997). In addition, the type of common play and the toys used may have an influence on maternal control behavior. At this point, it would be interesting to investigate whether there were gender-specific differences in the choice of the type of game and the toys used and whether these are related to the mothers' control behavior and its adequacy.

The value of our dynamic analysis is even more evident if we contrast it against the results of the static analysis, which (as reported above) shows that the intervention led to a higher (lower) probability of orientation (negative/lack of contingency) for girls, without qualifying the circumstances under which these improvements occurred, i.e. whether the girls were already displaying a positive behavior or not. Additionally, the static analysis does not uncover any intervention impacts for the mothers, while the dynamic analysis does so.

Finally, it is important to comment our findings in the light of the implementation difference between *Pro Kind* and the NFP Program in terms of home visitors' profession noted in the Methods section. While our results may not speak about the relative effectiveness of professionals versus para-professionals in the delivery of home visiting programs (Olds et al. 2004), they show that other professions than nurses may improve mother-child interactions; this is an important finding for future implementations of the NFP concept.

Conclusions

Our study is the first to examine the effects of a home visiting program on parent-child interactions using micro-social measures and dynamic modelling. Most previous studies (Love et al., 2005; Olds et al., 2004) have applied static models to scales with global coding, which do not fully capture the dynamics and the feedback effects of the repeated interactions between mother and child. The few previous studies (Beebe et al.,2009,2016) which have used dynamic models of mother-child interactions have not applied them to understand the impacts of a home visiting program. We have shown that it is important to account for these dynamics and cross-feedback effects to better understand the situations in which home visiting can improve the mother-child relationship.

Limitations

Despite its strength and novelty, the present study has some limitations. First, the duration of our video recordings is only three minutes. Longer (or repeated) recordings could reveal more nuanced patterns of interactions, in particular for behaviors that occur less frequently. Second, videos were only recorded when the child was 2 years of age. Videos at different ages would have allowed to analyze intervention impacts on mother-child interactions at different stages of child development (as for example in Meins et al., 2018). Third, there was no interrater reliability completed for the two codes. Fourth, the videos recorded only mother-child interactions. Therefore, we cannot say whether father-child interactions were improved by the home visits. Fifth, because of social desirability concerns, mothers may have shown more positive behavior during the video recordings than in their everyday interactions with their child. Sixth, the analysis sample is a subsample of the RCT, which might imply a reduced power; additionally, although we have shown that previous results based on the full sample can be replicated within our subsample, the external validity of our results should be taken with caution. Finally, the sample is a random draw from *Pro Kind* participants who took part in the interview 24 months after birth (45.8 % of the baseline sample). The attrition rate was higher than in some other studies with high-risk samples, such as the clinical studies of the NFP, because participants moved and changed their telephone numbers more often than expected when the *Pro Kind* study was designed. However, other analysis of the *Pro Kind* has showed that there is no differential attrition, so that treatment and control groups are still balanced at 24 months with respect to baseline characteristics (Sandner & Jungmann, 2017).

Implications

Our analysis has important implications. First, our methodology might be applied to other studies with detailed recordings of video-taped mother-child interactions, for example to deepen our understandings of the way home visiting programs work. Overall, it can be said that the Pro Kind program has a positive impact on the quality of mother-daughter interactions. Especially against the background of the lack of research results of other home visiting programs, our findings are of scientific importance. Furthermore, our results suggest that more attention needs to be devoted to the interactions between boys and their mothers in the design and implementation of future home visiting programs.

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Figure 1. CONSORT flow chart of the participants' progress

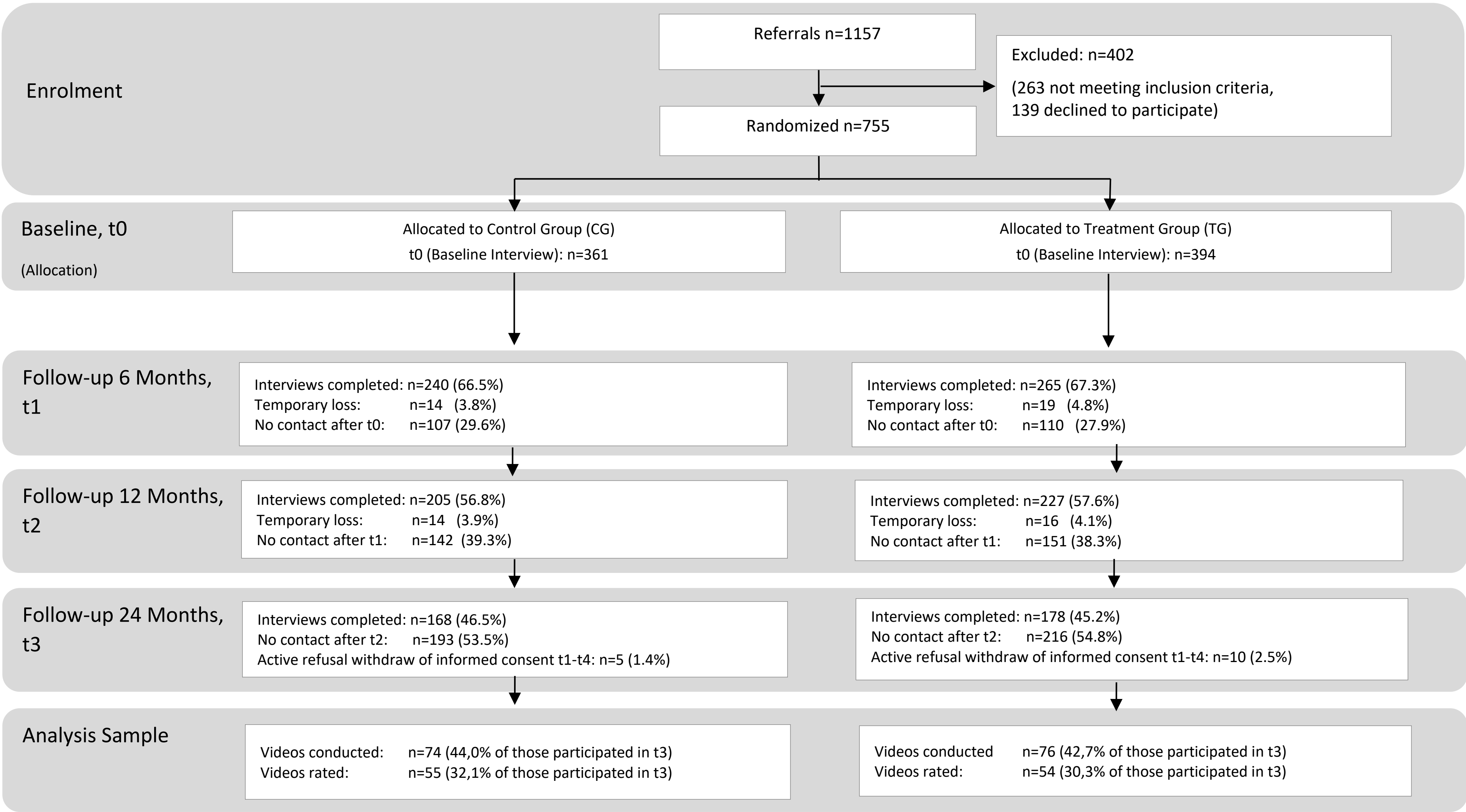

Figure 2. Pictogram of Interactions Scenarios

Note: Face icons indicate the behavior of the mother (top row) and the child (bottom row) observed in the previous time period (i.e. the preceding 5-second interval). Each column indicates one of the four hypothetical scenarios used in the analysis. A smiley face indicates a positive behavior (orientation=1, positive contingency=1, negative or lack of contingency=0), while a sad face indicates a negative behavior (orientation=0, positive contingency=0, negative or lack of contingency=1).

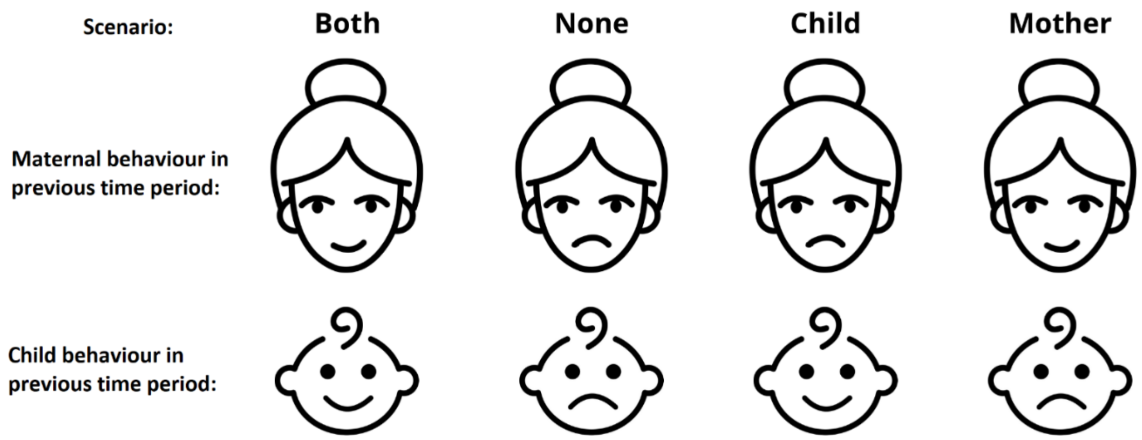

Table 1. Sample characteristics at baseline

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Variable	Categories	C	T	*p*	Female	Male	*p*	Full sample	Video sample	*p*
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	
Additional persons in Household	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		21.70	21.65	.480	21.55	21.83	.746	21.35	21.68	.466
Household income €/month		933.35	1,123.83	.093	976.99	1,079.57	.369	910.54	1,025.58	.052
Child's Birth Weight (grams)		3,225.9	3,374.5	.171	3,153.1	3,474.3	.003	3,280.6	3,298.8	.751

Notes: Columns (5), (8) and (11) report p-values of tests for the equality of means of selected baseline 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. In columns (3), (4), (6), (7), (9) and (10) we display frequencies for the discrete variables and means for the continuous variables. C = Control group, T = Treatment Group, p=p-value

Table 2. Correlation with Observable characteristics

	Overall	Girls	Boys	Wald Test
			Child Orientation	
Low BW	-27.76*	-40.88***	14.11	1.81
	(14.83)	(13.90)	(43.30)	*p* = .182
Cognitive 24m	0.62*	0.22	0.95*	1.36
	(0.31)	(0.39)	(0.50)	*p* = .246
			Child Contingency Positive	
Low BW	9.49	0.76	30.11	0.76
	(12.16)	(11.98)	(34.13)	*p* = .384
Cognitive 24m	-0.08	-0.27	-0.04	0.17
	(0.27)	(0.34)	(0.44)	*p* = .683
			Child Contingency Negative-Lack	
Low BW	8.93*	7.00	29.00*	2.67
	(4.89)	(4.46)	(14.52)	*p* = .106
Cognitive 24m	-0.25**	-0.20	-0.25	0.05
	(0.11)	(0.12)	(0.20)	*p* = .827
			Mother Orientation	
Risk Depression	-25.88***	9.65	-32.68**	3.91
	(9.41)	(16.45)	(12.27)	*p* = .051
			Mother Contingency Positive	
Risk Depression	-17.75*	11.05	-22.47**	2.47
	(9.30)	(18.13)	(11.08)	*p* = .119
			Mother Contingency Negative-Lack	
Risk Depression	6.90	7.72	7.18	0.09
	(5.52)	(9.11)	(7.95)	*p* = .769
			Self-rated Parenting	
Cognitive 24m	-1.088	1.525	-6.717	2.26
	(2.576)	(3.133)	(4.469)	*p* = .138
Observations	109	60	49	

*Notes: All measures are aggregated for each individual by taking the sum of the seconds each behavior is observed over the 3-minute recording. Risk Depression 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. Self-rated parenting scale (Arnold et al., 1993). Wald Test p-values are for the equality of coefficients between male and female samples. M=months. *** p<0.01, ** p<0.05, * p<0.1.*

Table 3. Treatment effects on outcomes (Probit Average Marginal Effects)

	All	Girls	Boys	Wald
Child Orientation				
Treat	0.04	0.15***	-0.09	9.47***
	(0.04)	(0.04)	(0.06)	*p* = .002
Control Mean	0.49	0.48	0.52	
Child Contingency Positive				
Treat	0.00	0.06	-0.07	3.63*
	(0.03)	(0.04)	(0.05)	*p* = .057
Control Mean	0.57	0.58	0.56	
Child Contingency Negative-Lack				
Treat	-0.04***	-0.034**	-0.04	0.075
	(0.01)	(0.02)	(0.02)	*p* = .785
Control Mean	0.07	0.06	0.08	
Mother Orientation				
Treat	-0.02	0.04	-0.09	3.10*
	(0.04)	(0.04)	(0.06)	*p* = .079
Control Mean	0.81	0.82	0.80	
Mother Contingency Positive				
Treat	-0.02	0.02	-0.07	1.58
	(0.03)	(0.04)	(0.05)	*p* = .209
Control Mean	0.66	0.67	0.64	
Mother Contingency Negative-Lack				
Treat	0.01	0.01	0.01	0.00
	(0.02)	(0.02)	(0.04)	*p* = .975
Control Mean	0.05	0.05	0.05	
Observations	3,924	2,160	1,764	

*Notes: Results are based on probit regression models for the overall sample and for girls and boys separately. Average Marginal Effects for the Treat variable are reported and show the percentage point difference between treatment and control groups. Numbers in parentheses are standard errors, clustered at the individual level. *** p<0.01, ** p<0.05, * p<0.1.*

Table 4. Predicted probabilities of different scenarios

Orientation		**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

Orientation		**Child**			**Mother**		
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

Contingency Positive		**Both**			**None**		
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

Contingency Positive		**Child**			**Mother**		
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

Contingency Negative-Lack		**Both**			**None**		
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

Contingency Negative-Lack		**Child**			**Mother**		
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 numbers in the "T" and "C" columns show the probability of orientation on the play situation for each partner for the treatment and control groups in each of the different scenarios presented in Figure 2. Numbers in parentheses are standard errors, clustered at the individual level. C = Control Group, T = Treatment Group; *** p<0.01, ** p<0.05, * p<0.1.*