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Published in:
Infant Behavior and Development

DOI:
10.1016/j.infbeh.2013.03.007

Publication date:
2013

Document version
Early version, also known as pre-print

Citation for published version (APA):
Væver, M. S., Krogh, M. T., Smith-Nielsen, J., Harder, S., & Køppe, S. (2013). Measuring spatial proximity in mother-infant interaction: A kinematic approach for an examination of the effects of maternal postpartum depression. *Infant Behavior and Development*, *36*(3), 427-431 . https://doi.org/10.1016/j.infbeh.2013.03.007

ELSEVIER

Infant Behavior & Development

An International and Multidisciplinary Journal

Infant Behavior & Development 36 (2013) 427–431

Contents lists available at SciVerse ScienceDirect

Infant Behavior and Development

Brief report

Measuring spatial proximity in mother–infant interaction: A kinematic approach for an examination of the effects of maternal postpartum depression

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ARTICLE INFO

Article history:
Received 3 January 2013
Received in revised form 15 March 2013
Accepted 26 March 2013

Keywords:
Spatial proximity
Mother–infant interaction
3D motion capture
Postpartum depression

ABSTRACT

A kinematic approach was used to measure mother–infant spatial proximity at 4 months. Maternal postpartum depression (PPD) impacts on mother–infant spatial interaction. We compared 28 dyads with mothers meeting criteria for PPD and 46 typical dyads. The PPD dyads had less variability in spatial proximity compared to typical dyads.

Spatial proximity is the distance between two people and the importance of spatial factors in human social and emotional behavior has been extensively reported by studies in more scientific fields. Hinde (1974) used proximity indices in studies of animals. Hall studied interpersonal distances and personal space. He conceived the personal space as a series of spatial spheres, called "bubbles", with the individual person as the center (Hall, 1966). According to Hall people regulate these "bubbles" to allow others into the more intense regions as a function of familiarity and affiliation. Proximity–distance and approach–avoidance are the foundational dimensions in the regulation of the spatial mother–infant emotional relationship and infant attachment as described by Bowlby (1969) and Ainsworth, Blehar, Waters, and Wall (1978). Early experiences of proximity, distance and security in non-verbal interactions may have enduring long-term effects on development of personality and individual style in regard to establish and enjoy both physical and psychological intimacy and closeness in a life-time perspective (Schachner, Shaver, & Mikulincer, 2005).

When interacting face-to-face, mothers and infants co-create a relational space. Directing head and gaze toward the partner and leaning forward, establish proximity. A direct face-to-face orientation indicates a strong psychological involvement. Likewise, distance and disengagement are established by leaning back and head aversion (Beebe & Stern, 1977; Costa, 2010). Infants have excellent spatial perception from birth. In response to a stimulus looming into the face on a collision course, infants duck their heads and put up their hands in a defensive reflex (Ball & Tronick, 1971). In face-to-face interactions mothers may sit upright, lean forward, or "loom" into the infant's face. Demetriades (2003, in Beebe et al., 2010) found that abrupt maternal transitions from upright to loom were more likely with higher maternal anxiety. Beebe et al. (2010) found that chase and dodge interactions (i.e. infant and the mother orienting away when the other is oriented toward) and mother's looming behaviors in 4-month dyads were related to infant being classified as resistant in attachment at 1 year.

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0163-6383/$ – see front matter
http://dx.doi.org/10.1016/j.infbeh.2013.03.007

Table 1
Background characteristics of the two groups.

Group	Typical dyads	PPD dyads
N	46	28
Gender	Male 20; female 26	Male 15; female 13
Mean mother age	30.6; SD = 4.2	30.9; SD = 3.9
Mother age range	23–43	23–39
Infant mean age	Mean = 4.0; SD = 0.2	Mean = 4.0; SD = 0.3
Mean years of education	Mean = 15.7; SD = 1.6	Mean = 15.5; SD = 1.5

Prenatal maternal attitudes are found to be significant predictors of mother–infant physical proximity at 6 months (Stoléru, Grinshpoun, Guillet, & Moralés-Huet, 1995) and postpartum depression is found to effect negatively on early mother–infant interactions. Maternal responsiveness is found to be reduced (Pearson et al., 2012) and infants of depressed mothers display more negative affect (Field, 2010). Two different interaction styles of depressed mothers have been identified, an intrusive and a withdrawn style. The intrusive style is associated with more maternal negative affect and the withdrawn style with more maternal passivity (Field, Diego, & Hernandez-Reif, 2006). Recent research using kinematic registration has measured and documented psychomotor disturbances as essential features of depressive disorders (Razavi et al., 2011). Depressed patients are found to differ from normal groups with regard to quantified gross motor activity level, movements of the limbs, trunk and head, speech and motor reaction time (Sobin & Sackheim, 1997). In a study of depressive symptoms in pregnancy and postpartum, psychomotor retardation/agitation was found to be among the best discriminating symptoms (Kammerer et al., 2009).

Previous investigations of spatial behaviors in mother–infant interaction have relied on manual coding of discrete infant and parental behavior (Beebe et al., 2010; Kaye & Fogel, 1980; van Egeren, Barratt, & Roach, 2001). Manual coding procedures are labor intensive and represent a limitation to large scale studies of subtle continuous behavioral changes in mother–infant interaction. The temporal precision of automated measurement is ideal for studying spatial behavior, and the use of kinematic registration is well established. Dowd and Tronick (1986) used a kinematic system to study infant limb temporal coordination with adult speech. Studies of motor development (Clifton, Rochat, Robin, & Berthier, 1994; Domellöf, Fargard, Jacquet, & Rönnqvist, 2011; Fetters, Sapir, Chen, kubo, & Tronick, 2009; Fitzpatrick, Schmidt, & Lockman, 1994; Shafir, Angulo-Barosso, Su, Jacobson, & Lozoff, 2009; Thelen, Corbetta, & Spencer, 1996; von Hofsten & Rönnqvist, 1988) have been using this technology with great success. There is a growing literature on the use of motion analysis to study social behavior. For example, Knoblich and Sebanz (2008) examined *joint action* and how individuals adjust their motor actions to those of another person in time and space. Becchio, Sartori, and Castiello (2010) examined the ways in which motor organization underlies social interaction.

However, to the best of our knowledge, kinematic registration for an automated measurement of spatial proximity in mother–infant dyads has not yet been explored. In this study we examine the feasibility of an automated method for measuring spatial proximity in a mother–infant standard face-to-face interaction at 4 months and examine differences in spatial proximity between dyads with typical mothers and dyads with mothers meeting criteria of PPD. We hypothesize: (i) the mean of spatial proximity will differ in the two groups, (ii) the percentage of time the two groups spend in different spatial proximity will differ and (iii) the variability in the use of relational space, i.e. the amount of changes between the 6 proximity categories will differ between the two groups.

Participants were 46 typical dyads and 28 dyads with mothers meeting criteria for PPD from a larger longitudinal study of mother–infant interaction. The initial screen for PPD required a score ≥10 on the Edinburg Postnatal Depression Scale (EPDS; Cox, Holden, & Sagovsky, 1987, Danish version, Breinholt Larsen, Ghoula, Wexel, & Videbech, 2009). EPDS mean was 15.0 (SD = 3.7; range: 10–23). After inclusion the severity of depression was assessed using Becks Depression Inventory (BDI-II; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961, Danish version, Pearson Assessment, 2005) based on the recommended cut-off scores: ≤13: none or minimal depression; 14–19: minor depression; 20–28: moderate depression; ≥29: severe depression. BDI-II mean was 25.1 (SD = 7.3; range: 14–43). Five women had a minor depression, 16 had a moderate depression and 7 had a severe depression.

Exclusion was due data from markers missing in more than 5% of the frames or excessive infant crying. All infants were Caucasian, full-term and had unremarkable pre- and postnatal medical histories. Typical mothers were recruited via web pages and by advertising at local obstetricians. PPD mothers were referred by community health nurses. All mothers were primiparous from urban Copenhagen. Mothers gave written informed consent (Table 1).

The lab visit was scheduled to fit into the infants' eating and sleeping patterns. The observation room was visually neutral and soundproof. Infants were seated in an infant chair placed on a table and mothers were seated opposite in a standard face-to-face setting (Tronick & Cohn, 1989). The distance between mother's and infant's heads was approximately 830 mm when mother was sitting upright (Fig. 1).

Mothers were instructed to talk and play with their infants as they normally would do at home without the use of toys for a period of 10 min. The first 5 min of the interaction was used for the analysis of the present study. For motion capture we used an eight-camera optoelectro registration system (ProReflex, 240 Hz; Qualiys Inc., Gothenburg, Sweden). Two spherical infrared passive reflective markers (diameter = 12 mm) were used for motion tracking in this study. One was placed on top of the mother's head fixated with hair pins. The other marker was placed on a cap worn by the infant. The system monitored

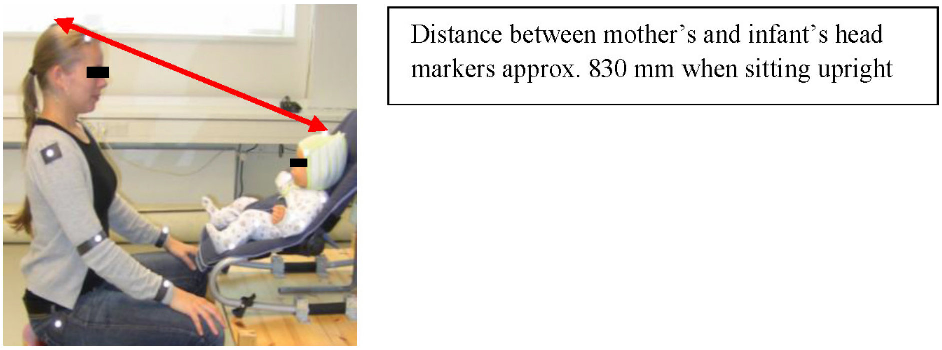

Fig. 1. The face-to-face situation and illustration of marker placement.

Table 2
Percentage of time spent in the proximity categories for the two groups.

	Very close 100–309 mm	Close 310–444 mm	Medium close 445–579 mm	Medium distant 580–714 mm	Distant 715–849 mm	Very distant 850–1100 mm	Total
Typical dyads	2.4%	14.8%	33.2%	34.6%	14.2%	0.8%	100
PPD dyads	1.4%	10.3%	33.6%	43.0%	9.7%	2.0%	100

Table 3
Means of number of times in each proximity category in the two groups.

	Very close 100–30 mm	Close 310–444 mm	Medium close 445–579 mm	Medium distant 580–714 mm	Distant 715–849 mm	Very distant 850–1100 mm	Total
Typical dyads	4.04	20.74	37.80	37.04	18.04	2.17	119.85
PPD dyads	2.86	15.25	33.25	32.54	13.21	2.32	99.43

the displacement of the markers at a frame rate of 60 Hz. Eight cameras were placed in a circle in the ceiling to optimize tracking of markers. Prior to the arrival of subjects the motion capture system was pre-calibrated to set the 3D space within the system. Calculations and filters were applied to the trajectory data using Qualisys Track Manager. All obtained data were filtered using a Moving Average procedure (Qualisys User Manual, 2012).

The kinematic parameter of spatial proximity was calculated as the distance between the two head marker trajectories projected on the three axes (X, Y and Z) for the 5 min period. To examine the use of the relational space in more details, and not simply comparing the overall mean of the two groups we developed an index of proximity categories. Based on the mean and standard deviation of spatial proximity in the typical dyads (mean = 579.6 mm; SD = 134.6 mm; range: 153–967 mm) the following 6 descriptive categories were developed:

(A) Very close (100–309 mm).
(B) Close (310–444 mm).
(C) Medium close (445–579 mm).
(D) Medium distant (580–714 mm).
(E) Distant (715–849 mm).
(F) Very distant (850–1100 mm).

The overall mean of spatial proximity in the two groups, percentage of time that each dyad spent in the 6 proximity categories and the number of times each dyad stayed in each category were calculated and compared for the two groups. The measurements of severity of depression were correlated with the proximity measures. All statistical analyses were performed using SPSS 19.0. Independent samples t-test was used to test for differences between the two groups.

Regarding hypothesis 1: There was no significant difference between the two groups in their overall mean of spatial proximity. The mean in the typical group was 579.6 mm (SD = 134.6 mm; range: 153–967 mm). In the PPD group the mean was 583.2 mm (SD = 122.9 mm; range: 168–1125 mm). There was no significant correlation between severity of depression (BDI score) and mean of proximity ($r = 0.295$, $p > 0.05$) (Table 2).

Regarding hypothesis 2: There were no significant differences in the percentage of time that the two groups spend in different categories of spatial proximity.

Regarding hypothesis 3: There was a significant difference between the two groups in the total amount of changes in spatial proximity. The PPD dyads had significantly fewer shifts between the 6 proximity categories ($p < 0.05$) (Table 3).

This difference had a medium effect size (Cohen's $d = 0.53$). The PPD group had 17% fewer shifts between the spatial proximity categories when compared to the group of typical dyads. No significant correlation between severity of depression (BDI score) and means of changes between proximity categories ($r = 0.056$, $p > 0.05$).

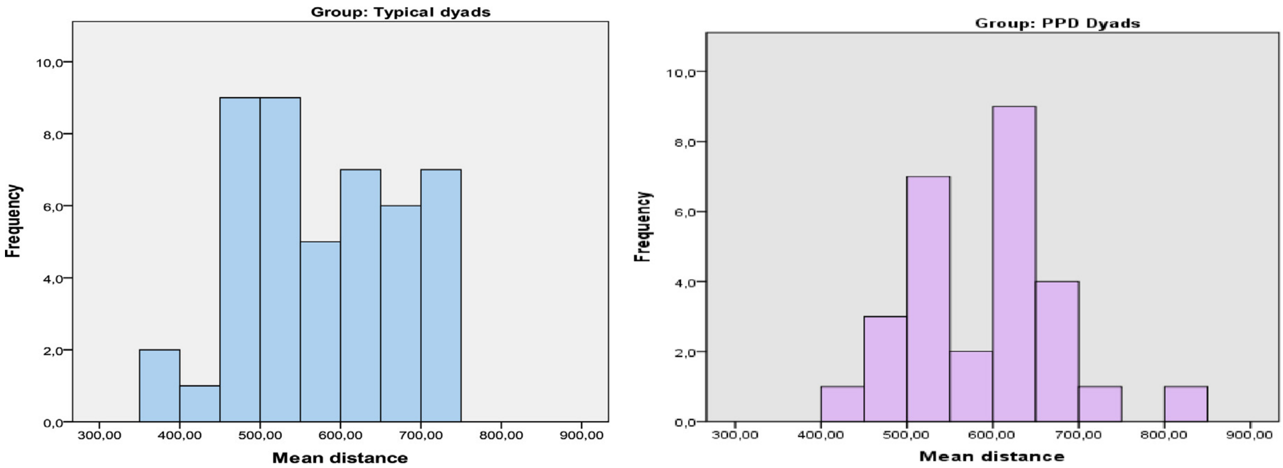

Fig. 2. Tables of means of spatial proximity for the two groups.

Using kinematic registration we measured the distance between mother's and infant's heads in a 5 min sample selection of a face-to-face interaction and we developed a proximity index. We compared a group of typical dyads and a group of dyads with mothers fulfilling criteria for PPD. We expected the two groups to differ in regard to the overall mean of spatial proximity and in regard to the variability and use of the relational space.

The PPD dyads had an overall higher mean of spatial proximity, i.e. they were more distant, than the typical dyads, however this difference was not significant. This finding is not surprising due to the distribution of the means of spatial proximity in the two groups (Fig. 2). The means of the PPD group fall in two clusters, one being in the closer range and another being in the distant range. Previous studies have shown PPD to impact on mother–infant spatial proximity and two interaction styles of mothers suffering from PPD are identified: too invasive/close and too passive/distant. Thus, we tested for differences regarding the percentage of time, that the two groups spent in the 6 proximity categories. Differences were seen, but none reaching the level of significance, and the two clusters seen in the graphics of the means were not confirmed. However, the sample size in this study is small and with a larger sample, the differences may reach significance. It should be noted that a low severity of depression in a PPD sample may in part also account for the lack of findings. The majority of women in this sample was classified as moderately depressed ($N = 16$), 7 women were classified as having a severe depression and 5 as mildly depressed. However, we found no significant correlation between severity of depression and the measures of proximity.

We expected the two groups to be different regarding the variability in their use of relational space, measured as amount of changes in spatial proximity. This was confirmed as the PPD dyads had 17% less shifts between the proximity categories than the typical dyads. This finding may confirm previous findings regarding psychomotor retardation as a core symptom in depression. Further it may inform us of how this impact on mother–infant interaction. Even though we measured spatial proximity as a dyadic measure (i.e. the distance between markers on mother's and infant's heads) the changes in spatial proximity at 4 months are primarily due to movement of the mother's torso and head. Thus, the finding of fewer changes in spatial proximity in the PPD dyads show that postpartum depressed mothers tend to move less when interacting with their infants. Further studies are needed to examine how this is related to maternal responsiveness and may impact on infant development and attachment.

Kinematic registration is not a quick error-proof method and a simple replacement for manual coding. For example data points can be lost when markers are obstructed. However, a kinematic approach is precise and timesaving, and the method used here proved feasible as it was able to differentiate the two groups. Studies employing automated measurement of spatial behaviors such as proximity may be used in large samples as well as these continuous measures may be used for more advanced statistical analysis. Use of it in future studies will deepen our understanding of spatial aspects of at-risk and typical mother–infant interaction that might be of importance for infant social and emotional development.

Acknowledgments

A fuller report will be provided upon request. This research was supported by grants from The Carlsberg Foundation, Inge Lehmann Foundation to the principal investigator Dr. Mette Væver. We are grateful to the study families and to the students at Copenhagen University Babylab for practical assistance.

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