Workflow: Annotated pdf, CrossRef and tracked changes

PROOF COVER SHEET

Author(s): Anne Sorariutta
Article title: Maternal sensitivity in responding during play and children's pre-mathematical skills: a longitudinal study from infancy to preschool age
Article no: PEDP 1140641
Enclosures: 1) Query sheet
2) Article proofs

Dear Author,

Please find attached the proofs for your article.

1. Please check these proofs carefully. It is the responsibility of the corresponding author to check these and approve or amend them. A second proof is not normally provided. Taylor & Francis cannot be held responsible for uncorrected errors, even if introduced during the production process. Once your corrections have been added to the article, it will be considered ready for publication

Please limit changes at this stage to the correction of errors. You should not make trivial changes, improve prose style, add new material, or delete existing material at this stage. You may be charged if your corrections are excessive
(we would not expect corrections to exceed 30 changes).

For detailed guidance on how to check your proofs, please paste this address into a new browser window: http://journalauthors.tandf.co.uk/production/checkingproofs.asp

Your PDF proof file has been enabled so that you can comment on the proof directly using Adobe Acrobat. If you wish to do this, please save the file to your hard disk first. For further information on marking corrections using Acrobat, please paste this address into a new browser window:http://journalauthors.tandf.co.uk/production/acrobat.asp

2. Please review the table of contributors below and confirm that the first and last names are structured correctly and that the authors are listed in the correct order of contribution. This check is to ensure that your names will appear correctly online and when the article is indexed.

Sequence	Prefix	Given name(s)	Surname	Suffix
1		Anne	Sorariutta	
2		Minna M.	Hannula-Sormunen	
3		Maarit	Silvén	

Queries are marked in the margins of the proofs, and you can also click the hyperlinks below.

Content changes made during copy-editing are shown as tracked changes. Inserted text is in red font and revisions have a blue indicator ⅄. Changes can also be viewed using the list comments function. To correct the proofs, you should insert or delete text following the instructions below, but **do not add comments to the existing tracked changes.**

AUTHOR QUERIES

General points:

1. **Permissions:** You have warranted that you have secured the necessary written permission from the appropriate copyright owner for the reproduction of any text, illustration, or other material in your article. For further guidance on this topic please see:
http://journalauthors.tandf.co.uk/copyright/usingThirdPartyMaterial.asp
2. **Third-party material:** If there is material in your article that is owned by a third party, please check that the necessary details of the copyright/rights owner are shown correctly.
3. **Affiliation:** The corresponding author is responsible for ensuring that address and email details are correct for all the co-authors. Affiliations given in the article should be the affiliation at the time the research was conducted. For further guidance on this topic please see: http://journalauthors.tandf.co.uk/preparation/writing.asp.
4. **Funding:** Was your research for this article funded by a funding agency? If so, please insert 'This work was supported by <insert the name of the funding agency in full>', followed by the grant number in square brackets '[grant number xxxx]'.
5. **Supplemental data and underlying research materials:** Do you wish to include the location of the underlying research materials (e.g. data, samples or models) for your article? If so, please insert this sentence before the reference section: 'The underlying research materials for this article can be accessed at <full link>/ description of location [author to complete]'. If your article includes supplemental data, the link will also be provided in this paragraph. See <http://journalauthors.tandf.co.uk/preparation/multimedia.asp> for further explanation of supplemental data and underlying research materials.
6. The **CrossRef database** (www.crossref.org/) has been used to validate the references. Changes resulting from mismatches are tracked in red font.

AQ1	Please provide the missing city for affiliation "a and b".
AQ2	Please clarify AUTHOR A, AUTHOR B and AUTHOR C are belongs to references if so please provide complete details.
AQ3	The CrossRef database (www.crossref.org/) has been used to validate the references. Mismatches between the original manuscript and CrossRef are tracked in red font. Please provide a revision if the change is incorrect. Do not comment on correct changes.

How to make corrections to your proofs using Adobe Acrobat/Reader

Taylor & Francis offers you a choice of options to help you make corrections to your proofs. Your PDF proof file has been enabled so that you can mark up the proof directly using Adobe Acrobat/Reader. This is the simplest and best way for you to ensure that your corrections will be incorporated. If you wish to do this, please follow these instructions:

1. Save the file to your hard disk.

2. Check which version of Adobe Acrobat/Reader you have on your computer. You can do this by clicking on the "Help" tab, and then "About".

   If Adobe Reader is not installed, you can get the latest version free from http://get.adobe.com/reader/.

3. If you have Adobe Acrobat/Reader 10 or a later version, click on the "Comment" link at the right-hand side to view the Comments pane.

4. You can then select any text and mark it up for deletion or replacement, or insert new text as needed. Please note that these will clearly be displayed in the Comments pane and secondary annotation is not needed to draw attention to your corrections. If you need to include new sections of text, it is also possible to add a comment to the proofs. To do this, use the Sticky Note tool in the task bar. Please also see our FAQs here: http://journalauthors.tandf.co.uk/ production/index.asp.

5. Make sure that you save the file when you close the document before uploading it to CATS using the "Upload File" button on the online correction form. If you have more than one file, please zip them together and then upload the zip file.

   If you prefer, you can make your corrections using the CATS online correction form.

Troubleshooting

Acrobat help:http://helpx.adobe.com/acrobat.html
Reader help:http://helpx.adobe.com/reader.html

Please note that full user guides for earlier versions of these programs are available from the Adobe Help pages by clicking on the link "Previous versions" under the "Help and tutorials" heading from the relevant link above. Commenting functionality is available from Adobe Reader 8.0 onwards and from Adobe Acrobat 7.0 onwards.

Firefox users: Firefox's inbuilt PDF Viewer is set to the default; please see the following for instructions on how to use this and download the PDF to your hard drive: http://support.mozilla.org/en-US/kb/view-pdf-files-firefox-without-downloading-them#w_using-a-pdf-reader-plugin

EUROPEAN JOURNAL OF DEVELOPMENTAL PSYCHOLOGY , 2016
VOL. XX, NO. X, 1–15
http://dx.doi.org/10.1080/17405629.2016.1140641

Routledge
Taylor & Francis Group

Maternal sensitivity in responding during play and children's pre-mathematical skills: a longitudinal study from infancy to preschool age

Anne Sorariutta[a], Minna M. Hannula-Sormunen[b] and Maarit Silvén[a]

[a]Department of Teacher Education, University of Turku, Finland; [b]Turku Institute for Advanced Studies, Department of Teacher Education, University of Turku, Finland AQ1

ABSTRACT

This longitudinal study explored how mothers' sensitivity in responding to their child's cognitive and emotional needs in infancy and toddlerhood predicts children's pre-mathematical skills at early preschool age. The sample consisted of 65 mother–child dyads ($N = 130$ individuals) videotaped during joint play at ages 1;0 and 2;0. The children's pre-mathematical skills were tested at age 3;0. The path analyses showed that, in infancy, mothers' autonomy support and scaffolding are more strongly related than emotional support to children's later performance on spatial and numerical tasks. The findings are discussed in relation to how maternal sensitivity in responding fosters children's pre-mathematical development in an optimal way.

ARTICLE HISTORY Received 19 March 2015; Accepted 4 January 2016

KEYWORDS Sensitivity; responsiveness; pre-mathematics; spatial; numerical

While there is ample evidence that children vary greatly in their pre-mathematical skills (e.g. Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Clements, Swaminathan, Hannibal, & Sarama, 1999; ~~AUTHOR B~~), we know relatively little AQ2 about the earliest social predictors of these individual differences at preschool age. Parents' speech and activities specific for mathematics have been related to children's proficiency in pre-mathematics (Blevins-Knabe & Musun-Miller, 1996; Gunderson & Levine, 2011; Pruden, Levine, & Huttenlocher, 2011). Other studies have linked general interactional processes to children's cognitive competence (Hirsh-Pasek & Burchinal, 2006; Martin, Ryan, & Brooks-Gunn, 2007). Our goal was to explore how parent–child interactions which constitute the first learning context in infancy and toddlerhood contribute to spatial and numerical outcomes at early preschool age.

CONTACT Anne Sorariutta anne.sorariutta@utu.fi

Parent–child interaction and development of pre-mathematical skills

Infants can relate spatial, temporal, and numerical information from birth on (de Hevia, Izard, Coubart, Spelke, & Streri, 2014). It is well documented that infants attend to properties and spatial relations of objects (Mix, Huttenlocher, & Levine, 2002; Quinn, 2007). These early perceptual experiences influence brain development and form the foundation of memory representations and core concepts which, in turn, shape later perception of quantitative and spatial relations between objects (Goswami, 2008). Research beyond infancy provides evidence that children's representations become gradually enriched as shown by their earliest vocabulary, including words for specific spatial and number concepts (Choi & Donough, 2007; Sarnecka, Goldman, & Slusser, in press). At preschool age, many children can produce the accurate cardinal number word for a set of three to four items and they use number sequence for counting larger sets of objects (e.g. ~~AUTHOR B~~; Wynn, 1990). They also understand basic spatial words (Loewenstein & Gentner, 2005), make judgements about object size (Gadzichowski, Pasnak, & Kidd, 2013), and they recognize shapes (Clements et al., 1999). We decided to assess children's spatial and numerical skills, given that few researchers have investigated both outcomes in the same study at early preschool age (but see Verdine et al., 2014).

Developmental theories posit a direct causal relationship between parenting behaviour and children's later outcomes in various domains. According to Vygotsky (1978), all higher forms of cognition originate from social interactions with others who provide appropriate and well-timed (non-)verbal guidance based on the novice learner's level of language and cognitive skills. Even though young children are initially dependent on parental scaffolding within the zone of proximal development, they become increasingly autonomous and competent over time as parents adjust their support to children's growing skills and interests (see also Wood, Bruner, & Ross, 1976). Sensitive responding refers to parents' ability to appropriately recognize infants' behavioural and emotional cues and to respond during interaction in a well-timed, reciprocal, and mutually rewarding manner (Ainsworth, Blehar, Waters, & Wall, 1978). As stated by Bornstein (1989), affective quality, contingency, and timing are the major characteristics of responsive behaviour.

An abundance of research on parenting behaviour has treated the dyads as the unit of analysis. The parents' emotional sensitivity in responding, as assessed by trained observers, has been studied extensively in relation to children's socio-emotional outcomes in infancy (e.g., meta-analysis by van IJzendoorn, 1995) but less with regard to early cognitive outcomes. It has been reported that parental behaviour representing cognitive responsiveness (e.g., NICHD Early Child Care Research Network, 2000), emotional sensitivity (e.g. Landry, Smith, Swank, Assel, & Vellet, 2001), or both combined (e.g. Hirsh-Pasek & Burchinal, 2006) predict children's overall cognitive development, including mathematical

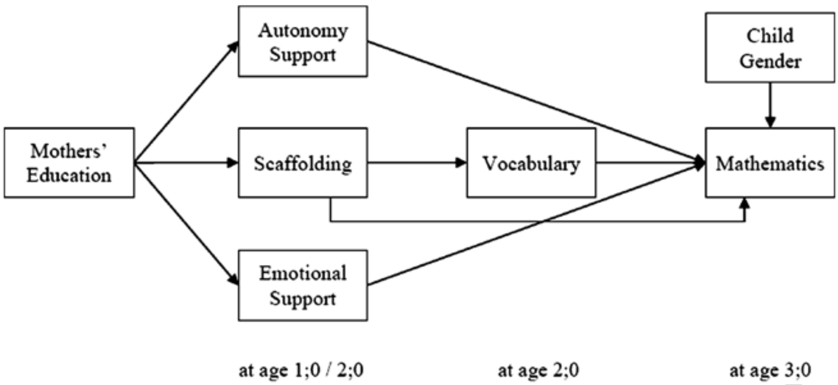

Figure 1. Hypothetical model illustrating relations between sensitivity in responding, pre-mathematical skills, and background variables.

tasks as one component. In addition, most of the longitudinal studies that have assessed cognitive and emotional aspects of parenting in infancy and toddlerhood have aggregated both these aspects into a multidimensional construct or composite score.

The present study

In a recent review on self-regulated learning, Pino-Pasternak and Whitebread (2010) have identified parenting behaviours, such as encouraging autonomy and providing cognitive and emotional support in a contingent fashion, that have an impact on children's performance on school-related tasks. No longitudinal studies have examined whether these different dimensions of parenting already in infancy (1; 0), as well as in toddlerhood (2;0), predict the learning and development of pre-mathematical skills at preschool age (3;0). Our major research question addresses this gap.

We observed mother–child dyads during play interactions, and tested children's spatial and numerical skill with age-appropriate tasks (see Clements et al., 1999; Plumert, Ewert, & Spear, 1995; Smith, 1984; Wynn, 1990; for corresponding procedures). On the basis of the literature review, we expected that higher levels of autonomy support, cognitive scaffolding, and emotional support would predict better performance on pre-mathematical tasks (see the hypothetical model, Figure 1). We applied path analyses to explore these relationships while controlling for the effects of mothers' educational status, child gender, and vocabulary, which have been shown to be related to developmental outcomes (e.g. Gunderson & Levine, 2011; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). We hypothesized that mothers' education indirectly influences child outcomes through mother–child interaction. In line with the Vygotskian view and studies on child language development (Bruner, 1983; for a review, see Tamis-LeMonda, Kuchirko, & Song, 2014), we assumed that cognitive scaffolding is associated with vocabulary in toddlerhood (2;0), which, in turn, predicts child outcomes. Although autonomy support has been related to developmental outcomes, it has not been associated with child language skills (Hindman & Morrison, 2012).

Method

Participants

We report data on 65 families of the Turku Longitudinal Study 1 (for more details, see ~~AUTHOR C~~). The children and their mothers (*N* = 130 individuals) were recruited from the files of the Population Registration Centre. The sampling criteria were first-born children of two-parent families living in a middle-to-large southern Finnish city. At the time of the first data collection the mothers were 21 to 37 years old (*M* = 27.9, ~~SD~~ = 5.0), and had 9 to 26 years' education (*M* = 14.7, ~~SD~~ = 3.6). The numbers of boys and girls were 25 (38%) and 40 (62%), respectively.

Assessments

Mothers' sensitivity in responding during play interactions

Mother–child dyads were videotaped for 10 minutes during a semi-structured joint play interaction at the age of 1;0 (±1 week) at home and at the age of 2;0 (±1 week) in a laboratory playroom. During both play sessions, the mother and child sat in their own chairs side by side at a table. The examiner put a set of small plastic toys representing animals, people, furniture, and other objects on the table and instructed the dyad to play just as they would normally do with the toys.

The 130 recordings were assessed using the Parent's Interactional Sensitivity with the Child (see ~~AUTHOR C~~). Two trained pairs of observers, one for each age level, independently rated the play sessions. The recordings were coded on a series of five-point scales (1, 1.5, 2, 2.5, and 3) by running each tape several times from second to second. Table 1 presents the 14 scales reflecting different cognitive and emotional aspects of mothers' sensitive responding to the child. A higher rating on each scale indicates that mothers' behaviour more often matches the description of the scale. A score of 3 on the cognitive scales describes a mother who predominately recognizes her child's cognitive states and goals, appropriately times and adjusts her guidance to the child's cognitive activities, and allows the child's to act independently. Similarly, a score of 3 on the emotional scales describes a mother who interacts in a highly affectionate and tender manner, for e.g., observes the child's emotional states and shares both positive and negative feelings. Lower scores describe a mother who "every

PEDP 1140641
19 January 2016
Initial
CE: BH QA: SM
Coll:XX QC:XX

Table 1. Cognitive and Emotional Scales of Parenting[a] (Explained Original Variance of PCA at Age 1;0 and 2;0 in Parenthesis).

Autonomy Support (76% and 85%)

1. The child mainly sets the goals for the activities even during moments of joint play between the child and the parent.
2. The parent allows the child's independent activities.
3. The parent controls and restricts the child's cognitive processes and occasionally even interrupts the child's activities in order to achieve her/his own goal. (scale reversed)

Scaffolding (67% and 83%)

4. The parent provides subtle guidance which respects and promotes the child's goals.
5. If the parent seeks to influence the child's goals, she/he sets the new goal slightly above the child's current goal and level of performance.
6. The parent assists and guides the child when necessary by dividing the problem into smaller more manageable tasks or breaking it up step by step into smaller sub-problems.
7. The parent adjusts her/his guidance to the child's level of cognitive development.

Emotional Support (68% and 78%)

8. The parent follows and becomes aware of the child's changing moods and emotional states even while being busy elsewhere.
9. The parent shares with the child both positive and negative feelings and succeeds in adjusting her/his own emotional state to that of the child.
10. The parent and the child look at each other and exchange smiles, and it can be concluded that the child is comfortable sharing things with the parent.
11. The parent interprets the child's emotional states. She/he shows to the child an understanding of how the child is feeling and takes the child's feelings into account as displayed through gestures, speech, and actions.
12. The parent helps the child to endure and cope with bad mood and distress in constructive ways. (scale omitted, rarely assigned values other than one)

Display of Emotions (86% and 74%)

13. The parent generally / occasionally / hardly ever expresses positive feelings in a genuine way.
14. The parent openly expresses negative feelings. (scale reversed)

[a]Cognitive scales = 1–7; Emotional scales = 8–14.

now and then" (score of 2) or "rarely" (score of 1) provides guidance or support or engages the child in mutual activity.

The intra-class correlation coefficients at 1;0 and 2;0 for cognitive guidance varied between .76–.86 and .76–.81, and for emotional support between .76–.91 and .73–.80, respectively.[1]

Vocabulary and pre-mathematical skills~~children's~~

vocabulary was assessed at 2;0 (±1 week) and their performance on spatial and numerical tasks at 3;0 (±1 week) using the Early Language Test (ELT, see ~~AUTHOR C~~). The tasks were developed for very young Finnish-speaking children, meaning that both age-specific and language-specific issues were taken into account during the testing and the coding procedure.

The children were tested at each age by a different trained female examiner. During testing, the child and the examiner sat side by side at the table in a playroom. The ELT material consisted of six sets of objects, each of which contained four objects. All items were toy replicas of real-world objects such

[1]The intra-class correlation coefficients at 1;0 and 2;0 for *Autonomy Support* varied between .76–.82 and .79–.80, for *Scaffolding* between .79–.86 and .76–.81, for *Emotional Support* between .76–.91 and .76–.80, and for *Display of Emotions* between .76–.90 and .73–.80, respectively.

as animals, people, and furniture, familiar to children from everyday routines. After being presented with a set, the child was allowed to play with the objects for 10–20 s. Thereafter, the examiner began to stimulate the child with standard questions about the objects. If the child's response was wrong, the examiner did not provide the correct answer. All assessment situations were videotaped for 15–20 min. The child's answers and reactions were analysed from the videotapes.

Vocabulary at 2;0

One point was given for each noun, verb, and adjective produced by the child during testing (~~AUTHOR C~~). Because only a few children spontaneously produced attributes, adjective vocabulary was excluded. The vocabulary score represents nouns and verbs and shows predictive validity for children's language development (~~AUTHOR C~~). The inter-rater reliability coefficients were .96 for nouns and .93 for verbs.

Size at 3; 0

In the large-small task, the examiner placed four animals on the table and asked how the horse is similar to the cow (about 4x7 cm in size) and how the dog is similar to the cat (about 2x4 cm in size). Next the examiner asked the child to put the large ones inside the empty animal pen. Then she placed all animals in the pen and asked the child to take out the small ones. In the tall-short task, the examiner placed four toy-people on the table and asked how the woman is similar to the man (about 8 cm) and how the girl is similar to the boy (about 5 cm). Next she asked the child to give her the tall ones. Then the examiner placed all the toy-people on the table and asked for the short ones. One score was assigned for each correct verbal response *large, small, tall,* and *short* and for each correct requested action. The maximum score is 8 ($M = 1.91$, ~~SD~~ = 1.01, range = 0–4).

Shape at 3; 0

In the round-square task, the examiner showed a ball to the child and asked what shape it is. Next she showed a building block and asked what shape it is. *Round* and *square* were scored as the correct answers. Next, the examiner placed a ball, a building block, a car, and a doll on the table and asked the child to give a round object and then a square object. Giving or pointing at the ball and the block were scored as the accurate actions. The maximum score is 4 ($M = 1.28$, ~~SD~~ = .72, range = 0–3).

Location at 3; 0

The examiner placed two toys, a table and a boy, on the table. Then she put the boy in different locations *on, under*, *beside*, and *behind* the table, and asked the child each time where the boy is. The following were scored as correct verbal responses for location: "on the table" *pöydän* | *päällä* [Table of | on] or *pöydä*|*llä*

[Table | on]); "under the table" *pöydän* | *alla* [Table of | under]; "beside the table" *pöydän* | *vieressä* [Table of | beside]; "behind" the table" *pöydän* | *takana* [Table of | behind]. In the second location task, the examiner asked the child to put the boy *on*, *under*, *beside*, and *behind* the table. Putting the boy in the correct location was scored as an accurate response. The maximum score is 8 ($M = 5.77$, SD = 1.66, range = 1–8).

Number at 3; 0

In the "Give me x items" task, there were four animals, four people, and four pieces of furniture on the table. The examiner asked for *one* person, *two* animals, and *three* pieces of furniture. One score was assigned for each accurate action. The maximum score is 3 ($M = 1.74$, SD = .73, range = 0–3).

The examiner introduced a baby doll to the child and dressed the doll in trousers, shirt, hat, and shoe. During the "How many items" task, the examiner posed the child questions about the number of the baby dolls' body parts. One score was assigned for each accurate verbal response: *one* for head, *two* for legs, *three* for head and hands, and *four* for legs and hands. The maximum score is 4 ($M = 1.03$, SD = .95, range = 0–4).

The alpha coefficients for the tasks varied from .46 to .64. Two trained observers rated independently a sample of 20 children. The inter-rater reliability coefficients varied from .82 to .96.

Results

Sensitivity in responding and pre-mathematical dimensions

Principal Component Analyses (PCA) were performed to obtain a smaller number of maternal predictor variables and child outcome variables. For use in the path analyses, scores on the principal component were constructed with the regression method in SPSS (2013). Table 2 shows the variation of the z-scores with mean 0 and variance 1. The PCAs on the correlations between the maternal scales in infancy and toddlerhood resulted in one- or two-component solutions with eigenvalues larger than 1 (see Table 1 for percentages of explained original variance). The PCAs regarding the seven cognitive scales distinguished *Autonomy Support* (scales 1, 2, 3) from *Scaffolding* (scales 4, 5, 6, 7). Similarly, the PCAs distinguished mothers' responsiveness to child's emotional needs (scales 8, 9, 10, 11) from mothers' display of positive and negative emotions (scales 13, 14). The former of these two dimensions, *Emotional Support* was used in the path analyses.

The PCA on the three spatial outcome variables showed that size and shape loaded high on the first principal component (explaining 55% of the original variance). Thus, we decided to keep the location variable as a separate outcome from *Size-Shape* which is in line with suggestions about object-based and

Table 2. Mothers' sensitivity in responding ($N = 66$) and children's pre-mathematical skills at 3;0 ($N = 65$): Range of Z-scores and ~~pearson~~ correlations.

	Range	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. *Autonomy Support* at 1;0	−2.40–1.26	-								
2. *Scaffolding* at 1;0	−1.58–1.85	.56	-							
3. *Emotional Support* at 1;0	−1.46–2.02	.45	.75	-						
4. *Autonomy Support* at 2;0	−1.80–1.70	.44	.44	.49	-					
5. *Scaffolding* at 2;0	−1.60–2.18	.45	.68	.55	.75	-				
6. *Emotional Support* at 2;0	−1.79–2.14	.40	.51	.58	.72	.74	-			
7. *Size-Shape*	−2.42–2.05	.40	.26	.10	.18	.33	.29	-		
8. Location	1–8	.41	.44	.38	.31	.34	.38	.11	-	
9. *Number*	−2.17–2.19	.33	.18	−.05	.39	.34	.37	.47	.20	-

Note. Parameter estimates in bold face are statistically significant, $p < .05$.

environment-based spatial concepts (Hegarty & Waller, 2004). The PCA on the two numerical variables also resulted in a one-component solution (percentage of explained variance was 63).

As shown in Table 2, the maternal predictors are more highly related at age 2;0 than age 1;0. The correlations between the maternal predictor and pre-mathematical outcome variables were mainly positive, ranging from fairly low to medium. The same was true (not shown in Table 2) for the maternal predictors and vocabulary ($r = .23–.42$), and for vocabulary and pre-mathematical outcomes ($r = −.02–.35$).

Mothers' sensitivity in responding and children's pre-mathematical skills

We used path analyses to examine whether mothers' sensitivity in responding predicts children's pre-mathematical skills, while controlling for the effect of mother's education and child vocabulary (Figure 1). The analyses were performed separately for *Size-Shape*, Location, and *Number*. In order to specify how the maternal predictors were related to differences in outcome variables, we first explored the effects of the predictors assessed at 1;0. The non-significant effects ($p > .05$) were removed one by one. Model fitting for the maternal predictors at 2;0 was done in the same way as for the maternal predictors at 1;0. Only the end results of the model fitting process are presented in Figure 2.

We applied Mplus 6.1 (Muthén & Muthén, 2010) to estimate the regression equations. The Maximum Likelihood Robust (MLR) estimation was chosen because it is robust to non-normality and the distributions of the variables were not normal throughout (West, Finch, & Curran, 1995). In evaluating the goodness-of-fit, we used three indicators suggested in the literature: the Chi-square > .05, the Comparative Fit Index (CFI) > .90 and the Root Mean Square Error of Approximation (RMSEA) < .08 (Hu & Bentler, 1995).

Figure 2(a) shows the path diagram of the *Size-Shape* model. Mothers' *Autonomy Support* in infancy, as well as children's vocabulary in toddlerhood,

PEDP 1140641
19 January 2016
Initial
CE: BH QA: SM
Coll:XX QC:XX

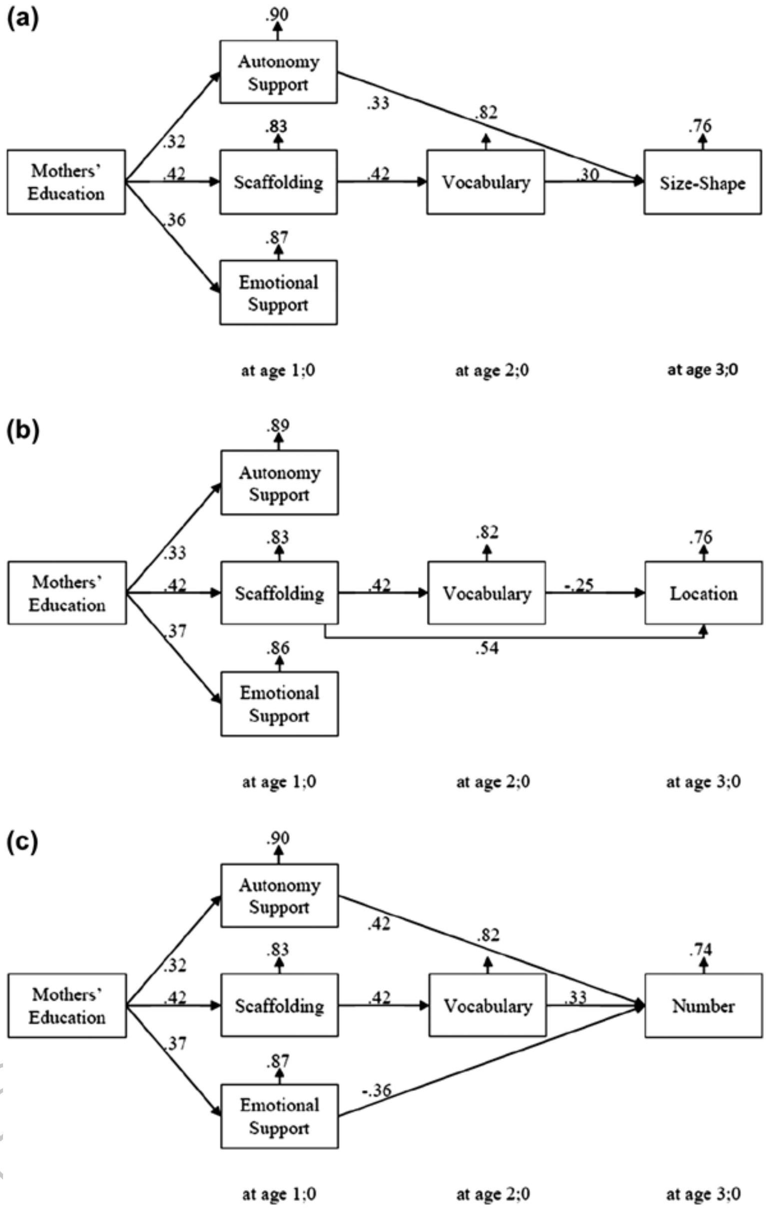

Figure 2. Mothers' Sensitivity in Responding as Predictor of Children's Pre-Mathematical Skills at 3;0. Standardized Regression Coefficients ($N = 65$).

Note. The fit statistics for (a): $\chi^2(5) = 2.96$, $p = .71$, CFI = 1.00, RMSEA = .00; (b): $\chi^2(4) = 2.64$, $p = .62$, CFI = 1.00, RMSEA = .00; (c): $\chi^2(5) = 7.95$, $p = .16$, CFI = .98, RMSEA = .09. The correlations between maternal predictors ranged from .33 to .70.

was positively associated with children's performance on the size and shape tasks. Moreover, mothers' *Scaffolding* had a positive direct effect on vocabulary and an indirect effect on task performance mediated by vocabulary (β = .13, z = 2.37). The model explained 24% of the variance. When running the corresponding model in toddlerhood, no statistically significant effects of the three maternal predictors were found.

In Figure 2(b), mothers' *Scaffolding* in infancy, as well as vocabulary in toddlerhood, were positively related to children's performance on the location tasks. However, vocabulary was a negative predictor, but the indirect effect of *Scaffolding* on Location was not significant. The model explained 24% of the variance. Running the corresponding model in toddlerhood, showed a positive effect of *Emotional Support* at 2;0 (β = .43, z = 4.35). The effect was no longer significant when the predictor was entered into the model in Figure 2(b).[2]

As shown by the *Number* model, Figure 2(c), mothers' *Autonomy Support* in infancy was associated with children's better performance, whereas *Emotional Support* predicted poorer performance on the number tasks. Again, *Scaffolding* had a positive direct effect on vocabulary and an indirect effect on task performance mediated by vocabulary (β = .12, z = 2.35). The model explained 26% of the variance. The corresponding model in toddlerhood showed a positive effect of *Autonomy Support* at 2;0 (β = .34, z = 3.06). Entering the predictor into the model at age 1;0, Figure 2(c), resulted in poor fit indices.

Figure 2(c) indicates that *Emotional Support* has a clearly stronger relationship with *Number* (β = –.36) than might have been expected on the basis of the zero-order correlation (r = –.05). The pattern of findings suggests a suppressor situation (Paulhus, Robins, Trzesniewski, & Tracy, 2004) which is further confirmed by the partial correlation (r = -.23, p = .07) when the effect of *Autonomy Support* is held constant. Correspondingly, the partial correlation between *Autonomy Support* and *Number* (r = .40) is somewhat higher than the zero-order correlation (r = .33) but equals the magnitude of the β value (.42).

Effects of background variables

As shown in Figure 2, more years of maternal education is related to higher levels of *Autonomy Support, Scaffolding,* and *Emotional Support,* which is in line with the zero-order correlations (r = .30–.42). There were significant indirect effects of mothers' education on Location through *Scaffolding* at 1;0 (β = .22, z = 2.80) and on *Number* through *Autonomy Support* at 1;0 (β = .13, z = 1.97) and *Emotional Support* at 1;0 (β = – .132, z = –2.74).

Figure 2(b) shows an increase in the magnitude of the negative effect of vocabulary on Location compared to the zero-order correlation, (r = –.02), but the partial correlation (r = –.24) equals the magnitude of the β value (–.25).

[2]We found stability in mothers' *Emotional Support* from infancy to toddlerhood (β = .58, z = 7.06).

Finally, in order to explore the stability of our results, we reran the regression models without maternal education, as well as with child gender. The predictive relations shown in Figure 2 remained practically the same.

Discussion

The main research question was which aspects of early mother–child play interaction predict later pre-mathematical outcomes. The results suggest that mothers who were more sensitive during joint play in infancy, as indicated by autonomy support and scaffolding, had children who performed better on spatial and numerical tasks. More highly educated mothers influenced later child outcomes as they responded more sensitively to their child's cognitive needs than mothers with less education. These relations hold true even after controlling for emotional support, child language and gender.

Many longitudinal studies exploring the effect of the multifaceted construct of parenting have merged emotional and cognitive aspects of interactional processes. Such a broad construct in toddlerhood has been shown to predict mathematical achievement at kindergarten age (Martin et al., 2007; for overall cognitive outcomes, see Hirsh-Pasek & Burchinal, 2006~~; NICHD Early Child Care Research Network, 2000~~). Instead of merging, we kept apart conceptually distinct parenting dimensions consistent with definitions of sensitive and responsive behaviour (Ainsworth et al., 1978; Bornstein, 1989). The same three dimensions have also been identified for older children (see Pino-Pasternak & Whitebread, 2010). As expected, inclusion of three related constructs indicated a suppressor situation in the path analyses. By removing child outcome-irrelevant variance of the maternal predictors, we could extract more efficient predictors that can have theoretical and practical importance (see also, Paulhus et al., 2004).

Our findings support recent evidence of the impact of early social experiences on neurobiological development. Mothers' scaffolding was the strongest predictor of children's performance on object location tasks at preschool age, as well as of vocabulary size in toddlerhood which is consistent with theory and research on child language development (see Bruner, 1983; Tamis-LeMonda et al., 2014), whereas mothers' autonomy support was a more powerful predictor of performance on tasks representing complex spatial and quantitative relations. According to the Vygotskian view, successful learning entails autonomy which gradually grows out of scaffolding. It is plausible that high-level parenting, already in infancy, when children acquire their basic memory representations of spatial and numerical concepts (McDonough, Choi, & Mandler, 2003; Quinn, 2007; Sarnecka et al., in press), is optimal for prompting later self-regulated learning.

Our evidence is consistent with prior findings on children's knowledge about the spatial relations (Clements et al., 1999; Gadzichowski et al., 2013) and quantitative relations (Wynn, 1990) of their physical environment. It is interesting that the pre-schoolers who performed better on object-based spatial tasks also performed better on cardinal number tasks for small sets of items. Thus far, the empirical evidence for this developmental relationship has been scarce (but see de Hevia et al., 2014; Verdine et al., 2014). Our findings on the effects of vocabulary size on later complex outcomes are in line with the view that learning nouns and verbs tunes children's attention to spatial and number words (Choi & Donough, 2007).

It turned out that high-level emotional support did not foster pre-mathematical development in an optimal way. Nonetheless, our findings do not imply that the emotional context of parent–child interaction would not be important per se or for other domains of development. Moreover, the path analyses in toddlerhood did not add to what interaction in infancy could explain for subsequent outcomes. Removal of the shared variance between the maternal predictors revealed no significant unique effects by any of the predictors in toddlerhood (mean of partial $r = .15$, range .03–.24, $p > .05$). One reason may be that Finnish mothers typically are the primary caretakers during the child's first year of life but, beyond infancy, other social relationships may emerge as unique predictors of development because fathers and professional caregivers have an increasing impact on learning.

Methodological considerations and conclusions

Some advantages and limitations in the present study should be taken into account. To reduce biased sampling the families were chosen from the register of the total population in Finland. The attrition rate over the three-year period was remarkably low. The sample size is small but typical for laborious micro-level coding of video-recorded play interaction, and for estimating regression models for dyadic data (Kenny, Kashy, & Cook, 2006).

All children were followed up at the exact ages, which is different from prior studies. Children have also been asked to count similar items presented in a single row (e.g. Wynn, 1990). Our numerical tasks were more demanding because the children had to count different types of body parts. Reanalysis of the *Number* model showed that the results stayed the same when including only the number words of one (head) and two (legs). Even though the task reliabilities were somewhat low, the upper limits of validity ranged from .68 to .80 (see Schmitt, 1996) and the inter-rater reliabilities were very high.

As it is the body parts that act with objects in the world (Smith, Maouene, & Hidaka, 2007), joint play might be a more valid early context for supporting cognitive outcomes compared to picture-book reading. Our study provides important new information for parents and early educators because mathematical performance before school entry forms a strong predictor of later school achievement (e.g. Aunola et al., 2004).

References

Ainsworth, M. D. A., Blehar, M. C., Waters, E., & Wall, S. (1978). *Patterns of attachment: A psychological study of the strange situation*. Hillsdale, NJ: Erlbaum.

Aunola, K., Leskinen, E., Lerkkanen, M.-K., & Nurmi, J.-E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology, 96*, 699–713. doi:10.1037/0022-0663.96.4.699. AQ3

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number use at home by children and their parents and its relationship to early mathematical performance. *Early Development and Parenting, 5*, 35–45.

Bornstein, M. H. (1989). *Maternal responsiveness: Characteristics and consequences*. San Francisco,CA: Jossey-Bass.

Bruner, J. (1983). *Child's talk: learning to use language*. New York, NY: Norton.

Choi, S., & Donough, Mc. (2007). Adapting spatial concepts for difference languages: From preverbal event schemas to semantic categories. In J. Plumert, & J. Spencer (Eds.), *The emerging spatial mind* (pp. 142–167). New York, NY: Oxford University Press.

Clements, D. H., Swaminathan, S., Hannibal, M. A. H., & Sarama, J. (1999). Young children's concepts of shape. *Journal for Research in Mathematics Education, 30*, 192–212.

de Hevia, M. D., Izard, V., Coubart, A., Spelke, E. S., & Streri, A. (2014). Representations of space, time, and number in neonates. *Proceedings of the National Academy of Sciences, 111*, 4809–4813. doi:10.1073/pnas.1323628111/-/DCSupplemental

Gadzichowski, K. M., Pasnak, R., & Kidd, J. K. (2013). What's odd about that? Exploring preschoolers' ability to apply the oddity principle to stimuli differing in colour, size, or form. *European Journal of Developmental Psychology, 10*, 739–751. doi:10.1080/17405629.2013.802648

Goswami, U. (2008). *Cognitive development: The learning brain*. Howe: Psychology Press.

Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number talk count more than others: Relations between parents' input and children's cardinal-number knowledge. *Developmental Science, 14*, 1021–1032. doi:10.1111/j.1467-7687.2011.01050.x.

Hegarty, M., & Waller, D. (2004). A dissociation between mental rotation and perspective-taking spatial abilities. *Intelligence, 32*, 175–191. doi:10.1016/j.intell.2003.12.001

Hindman, A. H., & Morrison, F. J. (2012). Differential contributions of three parenting dimensions to preschool literacy and social skills in a middle-income sample. *Merrill-Palmer Quarterly, 58*, 191–223.

Hirsh-Pasek, K., & Burchinal, M. (2006). Mother and caregiver sensitivity over time: Predicting language and academic outcomes with variable- and person-centered approaches. *Merrill-Palmer Quarterly, 52*, 449–485.

Hu, L., & Bentler, P. M. (1995). Evaluating model fit. In R. H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 76–99). London: Sage.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology, 27*, 236–248.

Kenny, D. A., Kashy, D. A., & Cook, W. L. (2006). *Dyadic data analysis*. New York, NY: Guilford.

Landry, S. H., Smith, K. E., Swank, P. R., Assel, M. A., & Vellet, S. (2001). Does early responsive parenting have a special importance for children's development or is consistency across early childhood necessary? *Developmental Psychology, 37*, 387–403. doi:10.1037/0012-1649.37.3.387

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50*, 315–353. doi:10.1016/j.cogpsych.2004.09.004

Martin, A., Ryan, R. M., & Brooks-Gunn, J. (2007). The joint influence of mother and father parenting on child cognitive outcomes at age 5. *Early Childhood Research Quarterly, 22*, 423–439. doi:10.1016/j.ecresq.2007.07.001.

McDonough, L., Choi, S., & Mandler, J. M. (2003). Understanding spatial relations: Flexible infants, lexical adults. *Cognitive Psychology, 46*, 229–259. doi:10.1016/S0010-0285(02)00514-5.

Mix, K. S., Huttenlocher, J., & Levine, S. C. (2002). *Quantitative development in infancy and early childhood*. New York, NY: Oxford University Press.

Muthén, L. K., & Muthén, B. O. (2010). *Mplus User's Guide* (6th ed.). Los Angeles, CA: Muthén, & Muthén.

NICHD Early Child Care Research Network. (2000). The relation of child care to cognitive and language development. *Child Development, 71*, 958–978.

Paulhus, D. L., Robins, R. W., Trzesniewski, K. H., & Tracy, J. L. (2004). Two replicable suppressor situations in personality research. *Multivariate Behavioral Research, 39*, 303–328. doi:10.1207/s15327906mbr3902_7.

Pino-Pasternak, D., & Whitebread, D. (2010). The role of parenting in children's self-regulated learning. *Educational Research Review, 5*, 220–242. doi:10.1016/j.edurev.2010.07.001.

Plumert, J. M., Ewert, K., & Spear, S. J. (1995). The early development of children's communication about nested spatial relations. *Child Development, 66*, 959–969.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science, 14*, 1417–1430. doi:10.1111/j.1467-7687.2011.01088.x.

Quinn, P. C. (2007). On the infant's prelinguistic conception of spatial relations: Three developmental trends and their implications for spatial language learning. In J. M. Plumert & J. P. Spencer (Eds.), *The emerging spatial mind* (pp. 117–141). New York, NY: Oxford University Press.

Sarnecka, B. W., Goldman, M. C., & Slusser, E. B. (in press). How counting leads to children's first representations of exact, large numbers. In R. Kadosh & A. Dowker, (Ed), *The Oxford handbook of numerical cognition* (pp. 291–308). doi:10.1093/oxfordhb/9780199642342.013.011

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment, 8*, 350–353.

Smith, L. B. (1984). Young children's understanding of attributes and dimensions: A comparison of conceptual and linguistic measures. *Child Development, 55*, 363–380.

Smith, L., Maouene, J., & Hidaka, S. (2007). The body and children's word learning. In J. M. Plumert & J. Spencer (Eds.), *The emerging spatial mind* (pp. 168–192). New York, NY: Oxford University Press.

Tamis-LeMonda, C., Kuchirko, Y., & Song, L. (2014). Why is infant language learning facilitated by parental responsiveness? *Current Directions in Psychological Science, 23*, 121–126. doi:10.1177/0963721414522813.

van IJzendoorn, M. (1995). Adult attachment representations, parental responsiveness, and infant attachment: A meta-analysis on the predictive validity of the adult attachment interview. *Psychological Bulletin, 117*, 387–403.

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematics skills. *Child Development, 85*, 1062–1076. doi:10.1111/cdev.12165.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

West, S. G., Finch, J. F., & Curran, P. J. (1995). Structural equation models with non-normal variables: Problems and remedies. In R. H. Hoyle (Ed.), *Structural equation modeling. Concepts, issues, and applications* (pp. 56–75). London: Sage.

Wood, D., Bruner, J., & Ross, S. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89–100.

Wynn, K. (1990). Children's understanding of counting. *Cognition, 36*, 155–193.