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Factor Structure and Measurement Invariance of the Prenatal Attachment Inventory: A Study among Japanese Pregnant Women

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Abstract

Background: Maternal emotional tie towards a foetus is a predictor of later maternal and child's mental health. **Methods:** A questionnaire survey was conducted among 539 first trimester women. It included the Prenatal Attachment Inventory (PAI), Relationship Questionnaire (RQ), and Edinburgh Postnatal Depression Scale (EPDS). The factor structure models derived from exploratory factor analyses were compared by confirmatory factor analyses. **Results:** A three-factor bifactor model of the PAI was bet fit to the data. The omega coefficients and explained common variance suggested that the influences of three group factors were not negligible. The scores of the three subscales (derived from the three factors) were differently associated with age, gestation week, and adult attachment styles (derived from RQ). They were, however, not correlated with the EPDS scores. **Conclusion:** The PAI has a model of three groups and one general factor with an excellent fit to the data. The three subscales have construct validity too.

Keywords

Prenatal Attachment Inventory, Maternal Emotional Ties, Factor Structure, Measurement Invariance

1. Introduction

Pregnant women develop emotional ties towards their foetuses. This has become a focus of research as early as the 1980s [1] [2] [3]. To quote Cranley [1], this tie is "the extent to which women engage in behaviours that represent an affiliation and interaction with their unborn child". More attention was paid to the emotional aspect of the tie by Condon [4]. He defined this as "the emotional tie or bond which normally develops between the pregnant woman and her unborn infant". Confusion has occurred around its conceptual definition. Many studies used the term "attachment" as the maternal tie to the foetus [4]. This idea came from the idea of attachment defined by Bowlby who referred to the baby's tie towards the caregiver. However, the tie mothers have towards a baby is a complement of the baby's attachment. Hence, many researchers prefer the term "bonding" [5].

The maternal bonding towards a foetus is of clinical importance. It ushers maternal bonding towards an infant after childbirth [6] [7] that is a determinant of the physical and psychological development of the child as well as the mothers' mental health [8] [9]. In a recent study, more attention has been focused on maternal attachment to a foetus [10].

Many instruments to assess parental bonding towards a foetus have been developed. They include the Maternal-Foetal Attachment Scale (MFAS) [1], Prenatal Attachment Inventory (PAI) [3], and Maternal Antenatal Attachment Scale (MAA) [2]. Despite the increasingly widespread use of these instruments, their psychometric properties have not been sufficiently reported.

This study reports the psychometric properties of the Japanese version of the PAI, one of the antenatal bonding instruments widely used. Müller [3] herself reported that she conducted exploratory factor analyses (EFAs) to yield five factors (factor loadings were not reported). However, this EFA used varimax rotation, an orthogonal rotation assuming non-correlation between factors. Psychological constructs are usually correlated to each other; therefore, should use diagonal rotation. Gau and Lee [11] conducted a confirmatory factor analysis (CFA) and reported a single-factor model with two covariances between error variables which reached an acceptable fitness (GFI = 0.90). However, they did not compare other factor models, such as a two-factor model, and they were unaware of whether the single factor model would show the best fit. Italian researchers also conducted an EFA using a Kaiser criterion (eigenvalue greater than unity) to determine the number of factors [12]. They presented a five-factor structure. They also did not compare different factor models. In addition, it is well known that Kaiser criteria often suggest an unduly large number of factors. EFAs were conducted by Pallant *et al.* [13]; however, they performed principle component analysis (PCA). PCA is often confused with EFA but these are statistically different and, in the efforts to identify the factor structure of the PAI, EFA should be conducted. Their CFA did not reach the recommended cut-off of comparative fit index (CFI) with 0.95 [14].

A reason that a factor model is a poor fit with the data may be the relatively large number of items of the PAI. This likely distorts the item number/factor ratio. Such an inappropriate item/factor ratio is very likely to produce a covariance of error variables, which violates the proposition of structural equation modeling. Second, a small number of anchor points of each item may violate the normality of the data. To address these drawbacks, we created parcels of PAI items [15] in the present analyses. Parceling is an aggregation of a few items into one or more composite variables. This improves the item/factor ratio and the normality of indicators (parcels), and results in less covariance between error variables. Hence, CFA of parcels rather than items can produce a more stable solution. Parceling methods are increasingly used in studies of psychometric properties. Three parcels per each factor were the recommended number [15]. Several means to create parcels have been proposed: 1) random algorithm, 2) factorial algorithm, 3) correlational algorithm, 4) radial algorithm, and 5) content-based algorithm. Of these, the random algorithm has been recommended [15].

This study compared the factor models derived from EFAs and cross-validated to determine the best fit model via CFAs. Construct validity was also examined.

2. Methods

2.1. Study Procedures and Participants

The data came from two collection periods (July 2016 to January 2017 and September 2018 to January 2019) where a set of questionnaires was distributed to pregnant women, at 26 weeks' gestation or later, attending an antenatal clinic. The researcher explained the purpose of the study and ensured the voluntariness of participation when the participants attended the clinic. Hence this is a convenient sample. Of 773 questionnaires that were distributed, 539 (70%) were returned. None of the participants had serious pregnancy complications. We did not ask the reason for declinature.

2.2. Measurements

Antenatal maternal bonding: We used the Japanese version [16] of the PAI. This is a self-report measure of maternal emotional ties to the foetus. The PAI consists of 21 items with a 4-point scale.

Current adult attachment: The current attachment to the partner was assessed by the Japanese version of the Relationship Questionnaire (RQ) [17]. The RQ is a self-report with 4 items and a 7-point scale (from 1 = "Does not apply to me at all" to 7 = "Applies to me very much"). These four items indicate different styles of adult attachment: Secure, Fearful, Preoccupied, and Dismissing. The participant was required to rate how each description would correspond to the women's relationship with the partner. We created two subscales: Positive Self- and Positive Other-models according to Bartholomew and Horowitz (1991). These were calculated as follows:

$$\text{Positive Self-model} = \text{Secure} - \text{Fearful} - \text{Preoccupied} + \text{Dismissing} \quad (1)$$

$$\text{Positive Other-model} = \text{Secure} - \text{Fearful} + \text{Preoccupied} - \text{Dismissing} \quad (2)$$

Depression: As a measure of depression, we used the Japanese version [18] of the Edinburgh Postnatal Depression Scale (EPDS) [19]. The EPDS is a self-report consisting of 10 items with a 4-point scale (0 to 3). Higher scores indicate more severe depressive symptoms. The psychometric properties of the EPDS were reported to be excellent [19].

2.3. Data Analysis

The whole dataset was divided into two groups, one (n = 279) for exploratory factor analyses (EFAs) and another (n = 260) for confirmatory factor analyses (CFAs) as a means of cross validation. For the first group, the factorability of the whole dataset (N = xxx) was examined by the Kaiser-Meyer-Olkin (KMO) index and Bartlett's sphericity test [20]. Also examined were the communality, skewness, and kurtosis of all PAI items. We then performed a series of EFAs. This was done by the maximum-likelihood method with PROMAX rotation from a single-factor structure and, subsequently, models with an increasingly greater number of factors (*i.e.*, two- and three-factor structures and so on). Because EFAs could not identify the best model to fit the data, we compared the goodness of fit of these models in a series of CFAs. The fit of models to the data was examined in terms of chi-squared, CFI, and RMSEA tests. Starting with the one-factor model, which is the most "parsimonious", the next model was accepted only when the decrease of χ^2 per df from the previous one was significant. Moreover, the absolute degree of fit with the data was judged using the following criteria: good if $\chi^2/df < 2$, CFI > 0.97, and RMSEA < 0.05; acceptable if $\chi^2/df < 3$, CFI > 0.95, and RMSEA < 0.08 [21] [22]. When the final model did not reach the level of CFI = 0.95 [14], we created parcels via factorial algorithms.

The internal consistency of the model was calculated by ω and ω_H. The omega coefficient is the preferable index of internal consistency of a psychological measure when the scale consists of more than one factor [23] [24] [25]. These indices are particularly useful for a bifactor model.

The proportion of variance of all items explained by all the factors is computed as follows:

$$\omega = \frac{\left(\sum_1^k \lambda_{\text{general}}\right)^2 + \left(\sum \lambda_{\text{group1}}\right)^2 + \left(\sum \lambda_{\text{group2}}\right)^2 + \left(\sum \lambda_{\text{group3}}\right)^2}{\left(\sum_1^k \lambda_{\text{general}}\right)^2 + \left(\sum \lambda_{\text{group1}}\right)^2 + \left(\sum \lambda_{\text{group2}}\right)^2 + \left(\sum \lambda_{\text{group3}}\right)^2 + \sum_1^k \delta} \quad (3)$$

where there are one general and three group factors. λ and δ refer to the factor loading and the variance of the item, respectively.

The proportion of variance of the items belonging to each group factor explained by the general and group factors is calculated as follows:

$$\omega_{\text{group1}} = \frac{\left(\sum_1^2 \lambda_{\text{gen}}\right)^2 + \left(\sum_1^2 \lambda_{\text{group1}}\right)^2}{\left(\sum_1^2 \lambda_{\text{gen}}\right)^2 + \left(\sum_1^2 \lambda_{\text{group1}}\right)^2 + \sum_1^2 \delta} \quad (4)$$

The proportion of variance of all the items explained only by the general factor is calculated as follows:

$$\omega_H = \frac{\left(\sum \lambda_{\text{general}}\right)^2}{\left(\sum \lambda_{\text{general}}\right)^2 + \left(\sum \lambda_{\text{group1}}\right)^2 + \left(\sum \lambda_{\text{group2}}\right)^2 + \left(\sum \lambda_{\text{group3}}\right)^2 + \sum \delta} \quad (5)$$

The proportion of variance of the items belonging to each group explained only by that group factor is calculated as follows:

$$\omega_{HS/\text{group1}} = \frac{\left(\sum \lambda_{\text{group1}}\right)^2}{\left(\sum_1^2 \lambda_{\text{gen}}\right)^2 + \left(\sum \lambda_{\text{group1}}\right)^2 + \sum_1^2 \delta} \quad (6)$$

In the case of a bifactor model, it is debatable whether the instrument is basically unidimensional (and group factors are negligible) or multidimensional (and group factor influences are substantial). Unidimensionality was checked and explained by common variance (ECV) [26] [27]. ECV is calculated as follows:

$$\text{ECV} = \frac{\left(\sum \lambda_{\text{general}}^2\right)}{\left(\sum \lambda_{\text{general}}^2\right) + \left(\sum \lambda_{\text{group1}}^2\right) + \left(\sum \lambda_{\text{group2}}^2\right) + \left(\sum \lambda_{\text{group3}}^2\right)} \quad (7)$$

2.4. Ethical Approval and Concent to Participate

This study was approved by the Institutional Review Board (IRB) of Saitama Prefectural University (No. 29535) on June 7th, 2016. Informed consent was obtained from each participant. All the participants gave written informed consent after understanding the study rationale and procedure. The authors assert that all procedures contributing to this study comply with the ethical standards of the National and Institutional Committees on human experimentation and with the Helsinki Declaration of 1975 as revised in 2008. All participants taking part in the study provided informed consent.

3. Results

In the first half of the sample (n = 279), only one item (item 3) showed skewness > 0.2. All the items showed kurtosis < 4.0 (**Table 1**). Hence all the items were subjected to EFAs. The data proved to be factorable: KMO = 0.904, sphericity χ^2 (df) = 2108.088 (210), $p < 0.001$. EFAs were started with a single factor model up to a four-factor model. In the single factor model, all the items showed factor loading greater than 0.3 [28] (**Table 2**).

Table 1. Mean, SD, skewness, kurtosis, and communality of the PAI items (n = 277).

PAI No.	Contents	M	SD	skewness	kurtosis
1	I wonder what the baby looks like now.	3.25	0.69	−0.38	−0.88
2	I imagine calling the baby by name.	3.07	0.81	−0.41	−0.67
3	I enjoy feeling the baby move.	3.77	0.50	−2.09	3.59
4	I think that my baby already has a personality.	2.82	0.95	−0.31	−0.86
5	I let other people put their hands on my tummy to feel the baby move.	2.94	0.92	−0.33	−0.92
6	I know things I will do make a difference to the baby.	2.90	0.87	−0.18	−0.95
7	I plan the things I will do with my baby.	2.94	0.85	−0.23	−0.90
8	I tell others what the baby does inside me.	2.58	0.95	0.03	−0.94
9	I imagine what part of the baby I'm touching.	3.13	0.89	−0.69	−0.28

Continued

10	I know when the baby is asleep.	2.89	0.91	−0.36	−0.76
11	I can make my baby move.	1.78	0.88	0.89	−0.09
12	I buy/make things for the baby.	2.96	0.85	−0.52	−0.30
13	I feel love for the baby.	3.62	0.61	−1.45	1.50
14	I try to imagine what the baby is doing in there.	3.19	0.81	−0.68	−0.30
15	I like to sit with my arms around my tummy.	2.58	0.94	−0.09	−0.89
16	I dream about the baby.	1.84	0.91	0.87	−0.13
17	I know why the baby is moving.	1.93	0.86	0.69	−0.14
18	I stroke the baby through my tummy.	3.60	0.60	−1.24	0.50
19	I share secrets with the baby.	1.72	0.98	1.13	0.06
20	I know the baby hears me.	2.33	0.99	0.31	−0.91
21	I get very excited when I think about the baby.	2.41	0.96	−0.38	−0.94

Table 2. Exploratory factor analysis of the PAI items (n = 277).

PAI item No.	Contents	1-factor model	2-factor model		3-factor model			4-factor model			
		I	I	II	I	II	III	I	II	III	IV
1	I wonder what the baby looks like now.	**0.63**	**0.63**	0.05	**0.41**	0.37	−0.07	**0.39**	0.39	−0.05	−0.01
2	I imagine calling the baby by name.	**0.68**	**0.59**	0.15	**0.44**	0.32	0.01	0.32	**0.42**	0.00	0.05
3	I enjoy feeling the baby move.	**0.49**	**0.67**	−0.14	−0.12	**0.72**	0.02	**0.74**	−0.11	0.02	−0.07
4	I think that my baby already has a personality.	**0.48**	**0.29**	0.24	0.14	0.21	0.22	−0.02	0.00	−0.00	**1.01**
5	I let other people put their hands on my tummy to feel the baby move.	**0.49**	0.26	0.27	**0.50**	−0.00	0.04	−0.03	**0.49**	0.01	0.13
6	I know things I will do make a difference to the baby.	**0.58**	0.29	**0.35**	0.20	0.19	**0.29**	0.13	0.19	0.22	**0.23**
7	I plan the things I will do with my baby.	**0.68**	**0.42**	0.32	**0.37**	0.23	0.19	0.27	**0.37**	0.21	−0.10
8	I tell others what the baby does inside me.	**0.69**	0.32	**0.44**	**0.87**	−0.11	0.02	−0.10	**0.86**	0.04	−0.02
9	I imagine what part of the baby I'm touching.	**0.58**	**0.44**	0.19	**0.57**	0.14	−0.07	0.13	**0.54**	−0.07	0.07
10	I know when the baby is asleep.	**0.50**	0.19	**0.37**	**0.43**	−0.01	0.15	0.03	**0.44**	0.19	−0.13
11	I can make my baby move.	**0.47**	−0.24	**0.80**	0.15	−0.23	**0.66**	−0.24	0.16	**0.64**	0.03
12	I buy/make things for the baby.	**0.51**	0.18	**0.38**	**0.40**	−0.02	0.19	0.01	**0.41**	0.22	−0.10
13	I feel love for the baby.	**0.52**	**0.76**	−0.19	−0.05	**0.77**	−0.05	**0.76**	−0.05	−0.07	0.03
14	I try to imagine what the baby is doing in there.	**0.67**	**0.76**	−0.03	0.29	**0.56**	−0.06	**0.56**	0.27	−0.07	0.05
15	I like to sit with my arms around my tummy.	**0.60**	**0.43**	0.22	0.26	**0.28**	0.15	**0.27**	0.24	0.13	0.09
16	I dream about the baby.	**0.45**	−0.05	**0.58**	0.07	−0.04	**0.52**	−0.03	0.08	**0.52**	−0.02
17	I know why the baby is moving.	**0.58**	−0.21	**0.91**	0.23	−0.23	**0.72**	−0.23	0.23	**0.71**	0.01
18	I stroke the baby through my tummy.	**0.50**	**0.62**	−0.08	0.26	**0.45**	−0.12	**0.45**	0.25	−0.13	0.01
19	I share secrets with the baby.	**0.42**	0.06	**0.42**	−0.04	0.09	**0.46**	0.11	−0.03	**0.48**	−0.06
20	I know the baby hears me.	**0.57**	0.14	**0.50**	−0.19	0.25	**0.67**	0.19	−0.21	**0.62**	0.20
21	I get very excited when I think about the baby.	**0.61**	0.31	**0.37**	−0.13	0.38	**0.51**	**0.42**	−0.14	0.55	−0.11

+ reverse item. Factor loading greater than 0.3 in bold.

In the model comparison via CFAs using the second half sample (n - 260), the single factor model showed a poor fit. Compared to this model, the two-factor model was superior. Likewise, the three-factor model was superior to the two-factor model. However, the four-factor model showed a worse fit than the three-factor model (**Table 3**). Hence, the three-factor model was the best among these factor models. The best model was built using parcels. The first factor loaded items such as "I tell others what the baby does inside me" and "I know when the baby is asleep". We interpreted this as a Vivid Image of the Foetus. The second factor loaded items such as "I enjoy feeling the baby move" and "I stroke the baby through my tummy". We interpreted this as Tactile Closeness to the Foetus. The third factor loaded items such as "I know why the baby is moving" and "I know the baby hears me". We interpreted this as Perception of the Foetus as an Individual.

The above three-factor model, however, did not reach an acceptable level (CFI = 0.961). Therefore, we created parcels for each factor depending on the factorial algorithm. This showed a good fit: χ^2/df = 1.537, CFI = 0.987, and RMSEA = 0.046. The fit indices became better when we added a general factor to make a bifactor model: χ^2/df= 0.976, CFI = 1.000, and RMSEA = 0.000 (**Table 4**).

The internal consistency of the whole instrument meassured by ω was 0.917 (**Table 4**). This means that all the specific and general factors explained more than 90% of the variance of the instrument. On the other hand, the proportion of variance explainded by each factor expressed by ω_H and ω_{HS} was 0.826, 0.105, 0.267, and 0.236 for the general factor, the Vivid Image of the Foetus factor, the Tactile Closeness to the Foetus factor, and the Perception of the Foetus as an Individual factor, respectively. This means that more than 80% of the vaiances of all the parcels were explained by the general factor whereas the parcels belonging to each specific factor were only moderately explained by each specific factor. ECV of the general factor was 0.719. This suggests that the proportion of variance explained by the general factor was substantial but the specific factors' contribution was not negligible.

We created composite subscale scores according to the factor structure: Vivid Image of the Foetus, Tactile Closeness to the Foetus, Perception of the Foetus as an Individual, and total scores. These scores were differentially correlated with the other variables (**Table 5**). Thus, age was negatively correlated with Perception

Table 3. Model comparison of the PAI factor models by confirmatory factor analysis (n = 260).

Model	χ^2	df	χ^2/df	$\Delta\chi^2$	CFI	ΔCFI	RMSEA	ΔRMSEA
1-factor	550.689	189	2.914	Ref	0.777	Ref	0.086	Ref
2-factor	460.248	188	2.448	90.441 (1)***	0.832	0.055	0.075	0.011
3-factor	411.612	186	2.213	48.636 (2)***	0.861	0.029	0.068	0.007
4-factor	449.513	183	2.456	Δ37.901 (3)	0.836	Δ0.025	0.075	Δ0.007

***$p < 0.001$.

Table 4. CFA of the PAI item parcels.

Pacels	General factor	Specific factor 1	Specific factor 2	Specific factor 3
Parcel 11 (items 1, 7, and 12)	0.779***	−0.051		
Parcel 12 (items 2, 8, and 10)	0.746***	−0.169		
Parcel 13 (items 5 and 9)	0.682***	−0.607		
Parcel 21 (items 3 and 18)	0.535***		−0.550***	
Parcel 22 (items 13 and 15)	0.590***		−0.407***	
Parcel 23 (item 14)	0.661***		−0.328*	
Parcel 31 (items 4, 16, and 21)	0.669***			−0.234*
Parcel 32 (items 6, 17, and 20)	0.706***			−0.594**
Parcel 33 (items 11 and 19)	0.545***			−0.398**
ω/ω_S	0.917	0.851	0.782	0.813
ω_H/ω_{HS}	0.826	0.105	0.267	0.236

$^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table 5. Correlations between the three suscales scores with age, gestation week, adult attachment, and EPDS scores (N = 535).

	Vivid Image of the Foetus	Tactile Closeness to the Foetus	Perception of the Foetus as Individual	Total
Age	−0.14**	−0.07	−0.16***	−0.15**
Gestation week	0.17***	0.04	0.10*	0.14**
Self model	0.21***	0.22***	0.09*	0.19***
Other model	0.17***	0.22***	0.13**	0.19***
EPDS	−0.03	−0.11*	0.12**	0.01

EPDS, Edinbugh Postnatal Depression Scale. $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

of the Foetus as an Individual but only slighty with Vivid Image of the Foetus and the total score. Higher gestation week was correlated with Vivid Image of the Foetus and only slightly with the total score. Self and Other models were correlated with Vivid Image of the Foetus, Tactile Closeness to the Foetus, and the total score but only slightly with Perception of the Foetus as an Individual. The total EPDS scores were only slightly correlated with Perception of the Foetus as an Individual.

4. Discussion

This study revealed the complicated factor structure of the PAI. The PAI has three specific and one general factors. It is rather unidimensional as suggested by Gau and Lee [11] but the specific (group) factors are not necessarily negligible. The maternal emotional tie towards a foetus may have multiple facets and yet have a core of it. The core of the mother-to-foetus tie can appear in the domain of representation of the foetus in the womb, tactile approach to the foetus, and recognition of the foetus as an independent existence as a person. This is clinically interpretable and may be used in support and care for expectant women.

The maternal tie towards a foetus was correlated with better adult attachment (towards the partner) and, though to a lesser extent, later gestation week and younger age. These correlations were different between the specific factors. Thus, Vivid Image of the Foetus and Tactile Closeness to the Foetus was significantly ($p < 0.001$) correlated to better adult attachment whereas Perception of the Foetus as an Individual was significantly correlated with younger age.

The clinical implication of this study includes several points. Because better maternal ties with the foetus predict better maternal and infant health conditions, more attention should be paid to expectant mothers' emotional aspects related to a foetus. Careful observation is recommended in routine assessment. Mothers with a poor emotional tie towards the foetus should be provided with nursing care and treatment. The fact that the maternal tie towards a foetus is associated with the mother's attachment to the partner suggests that antenatal nursing care should expand its territory from the care for the woman to include that of her partner. A more aggressive care plan may be recommended to include the partner as well as the couple as a target of intervention. In order for perinatal health professionals to identify those expectant women with bonding difficulties, the PAI may be a strong tool to be used in a very busy clinical setting.

The present study is not without limitations. We recruited nulliparous women. Different results may be observed among multiparous women. We excluded women with pregnancy complications. Such women may, however, be faced with a difficult situation to develop healthy emotional ties with a foetus. We did not conduct face-to-face interviews. Such clinical interviews may provide wider and deeper perspectives.

Taking into consideration these drawbacks, this study suggests that the PAI is a clinically useful and statistically robust measure of maternal ties towards a foetus. It also suggests that we should pay attention not only to emotional ties but also its different aspects measured by the PAI.

Data availability

Data set used in this study may be available upon reasonable request to the first author.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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