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ORIGINAL ARTICLE

Sleep-deprived new mothers gave their infants a higher priority than themselves

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Abstract

Aim: To understand why some parents are less sensitive to infant cues than others, we need to understand how healthy parents respond, and how this is influenced by factors such as sleep deprivation. Here, we examined whether sleep deprivation alters the self-infant-prioritisation effect in a population of first-time mothers within their first year of motherhood.

Methods: The study took place at Aarhus University Hospital in Denmark from August 2018 until February 2020. First-time mothers were recruited through Midwife clinics, national and social media. All women completed a perceptual matching task including an infant category. The mothers were divided into two groups depending on their sleep status: below or above 7h of average night-time sleep, measured with actigraphy.

Results: Forty-eight first-time mothers at the age of 29.13 ± 3.87 years were included. In the sleep-deprived group, the infant category was statistically significantly higher in accuracy ($p = 0.005$) and faster in reaction time ($p < 0.001$) than all other categories. In contrast, in the non-sleep-deprived group, there was no statistically significant difference between self and infant, neither in accuracy, nor reaction time.

Conclusion: Sleep-deprived new mothers strongly prioritised infants over self, while non-sleep-deprived new mothers showed no prioritisation of the self over the infant.

KEYWORDS
infant, parenting, perception, self-concept, sleep

1 | INTRODUCTION

Becoming a parent for the first time is a life-changing event, often followed by a period of sleep disruption due to the newest addition to the family. The sleep disruption experienced within the first year of parenthood can be rather intrusive. A study examining the epigenetic age of new mothers before and 1 year after birth-giving found accelerated biological ageing of mothers who on average slept <7 h per night.[1] This effect was only significant for sleep duration, while there was no correlation between subjective sleep quality and biological ageing.[1] Moreover, sleep research has found that the longer time you sleep <7h per night in a row, the more attention lapses you have.[2,3]

For several decades, researchers have examined how humans navigate and prioritise information. Hence, a self-prioritisation

effect has been found in different cognitive domains such as attention, perception, memory and decision making.[4–7] This self-prioritisation is thought to help us navigate between social salient and less salient information, which in turn influences human behaviour.[5–9]

Until 2022, no studies had examined the life-changing effects of parenthood on the self-prioritisation effect. A study by Høgholt et al.[10] included an infant category in a perceptual matching task and found a shift from self-prioritisation to infant prioritisation in first-time parents. This demonstrated the profound behavioural changes occurring when becoming a parent for the first time.

The self-prioritisation effect has been shown to depend on several brain networks including the ventromedial prefrontal cortex and the left posterior superior temporal sulcus.[4,6,7,11] The activity of these areas are affected by sleep deprivation, along with large brain networks involved in attention, memory, emotions, decision making, and resting-state networks.[9,12–15] Hence, we hypothesise that the self-infant-prioritisation effect is modified during sleep deprivation.

In this study, we used a modified version of the perceptual matching task including an infant category[10] to investigate the self-infant-prioritisation effect in new first-time mothers where some were sleep deprived and some were not.

2 | METHODS

2.1 | Participants

The study recruited 48 first-time mothers. After data collection, the participants were divided into two groups based on their total amount of night-time sleep. The mothers sleeping on average above 7h of night-time sleep will be referred to as the *non-sleep-deprived group*, while the mothers sleeping on average below 7h of night-time sleep will be referred to as the *sleep-deprived group*. There were no statistically significant differences between the two groups. See Table 1 for group characteristics. All participants were recruited through social media such as Facebook, local and national media, and bulletin boards in public areas. Before inclusion, all participants were screened for inclusion and exclusion criteria (see below) and filled out a consent form. The study was approved by the Ethics Committee of the Central Denmark Region (approval number: 2021-41) and was conducted at Aarhus University Hospital from August 2018 until February 2020, when it was stopped due to the COVID-19 pandemic. The Declaration of Helsinki was followed in all experimental procedures.

The participants included were healthy first-time mothers with an age above 18years. The exclusion criteria were: a score of 11 or above on the Edinburgh Postnatal Depression Score; comorbid psychiatric disorder; use of sleep medication; caffeine intake on the day of data collection; a history of sleep disorders; more than two night shifts per week; and uncorrected visual impairment causing inability to participate in the visual test.

Key Notes

- To understand why some parents are less sensitive to infant cues than others, we need to understand how healthy parents respond, and how this is influenced by factors such as sleep deprivation.
- For the first time, we show how infant prioritisation is enhanced when being a healthy sleep deprived first-time mother.
- We suggest to investigate the self-infant-prioritisation effect in women suffering from postnatal depression.

2.2 | Study design

The study was designed as a cross-sectional behavioural study. After inclusion, the participants were equipped with a GENEActiv original actigraph (Activinsights). An actigraph is an accelerometer that detects movement during sleep and is used to estimate different sleep parameters, such as total night-time sleep. The participants were also asked to fill out a 7-day sleep diary. The participants had their daily activity and sleep measured continuously with the actigraphy and filled out the sleep log for 1week before and after the day of testing, resulting in sleep data for 2weeks in total.

The study was not preregistered, and data and code will be made available on reasonable request. See the experimental design in Figure 1. For details on procedure, stimuli, task, the Postpartum Bonding Questionnaire[16,17] and Edinburgh Postnatal Depression Scale,[18] please refer questionnaire section on page 1 of the Appendix S1.

2.3 | Analysis

For each trial, accuracy and reaction time was recorded, and data were stored as text files. The data were extracted into a Microsoft Excel sheet using a (Visual studio 2019) C++ script. After extraction, we excluded all trials with a reaction time below 150ms, as this was considered non-conscious. Next, we identified and excluded outliers using the robust regression and outlier removal method in Prism 9 software.[19] This was carried out with a Q set at 1%. In total, 5.9% of the trials were removed. The remaining trials were grouped according to shape category: infant, self, mum, friend and stranger. Furthermore, the data were divided depending on whether the label had matched or not, thus creating 10 different groups in total, with a matched and non-matched version of all five categories (Figure 1). The number of included trials per category for the good sleepers varied between 855–879 trials and 749–791 trials for the bad sleepers, giving an average amount of trials per category per participant of 34.55 for the non-sleep-deprived group (34.55 ± 0.09) and 33.1 (33.01 ± 0.35) for the sleep-deprived group. Hence, the sleep-deprived group missed more trials on a statistically significant level ($p = 0.00001$).

TABLE 1 Demographics of the two groups

|	Above 7 h (n = 25)	Below 7 h (n = 23)	p-value[a]	All mothers (n = 48)
Age (years)	29.2 ± 3.34 (n = 25)	29.04 ± 4.45 (n = 23)	0.7736	29.13 ± 3.87 (n = 48)
Infant age (month)	7.22 ± 1.85 (n = 25)	7.45 ± 2.36 (n = 23)	0.6948	7.33 ± 2.09 (n = 48)
Fertility treatment	1 (4.8%) (n = 21)	3 (14.3%) (n = 21)	0.3106	4 (9.5%) (n = 42)
Educational level[b]	2.8 ± 2.74 (n = 25)	2.7 ± 2.66 (n = 23)	0.9655	2.75 ± 2.70 (n = 48)
Bonding	6.87 ± 4.31 (n = 15)	6.85 ± 3.24 (n = 13)	0.6104	6.85 ± 3.78 (n = 28)
EPDS	4 ± 2.27 (n = 25)	4.29 ± 3.05 (n = 21)	0.2984	4.13 ± 2.63 (n = 46)
Lefthanded	1 (4%) (n = 25)	3 (13%) (n = 23)	0.2717	4 (8.3%) (n = 48)

[a]Mann–Whitney U-test.

[b]Scored from 0–7 based on the Educational levels defined by the Danish Ministry of Children and Education.[29]
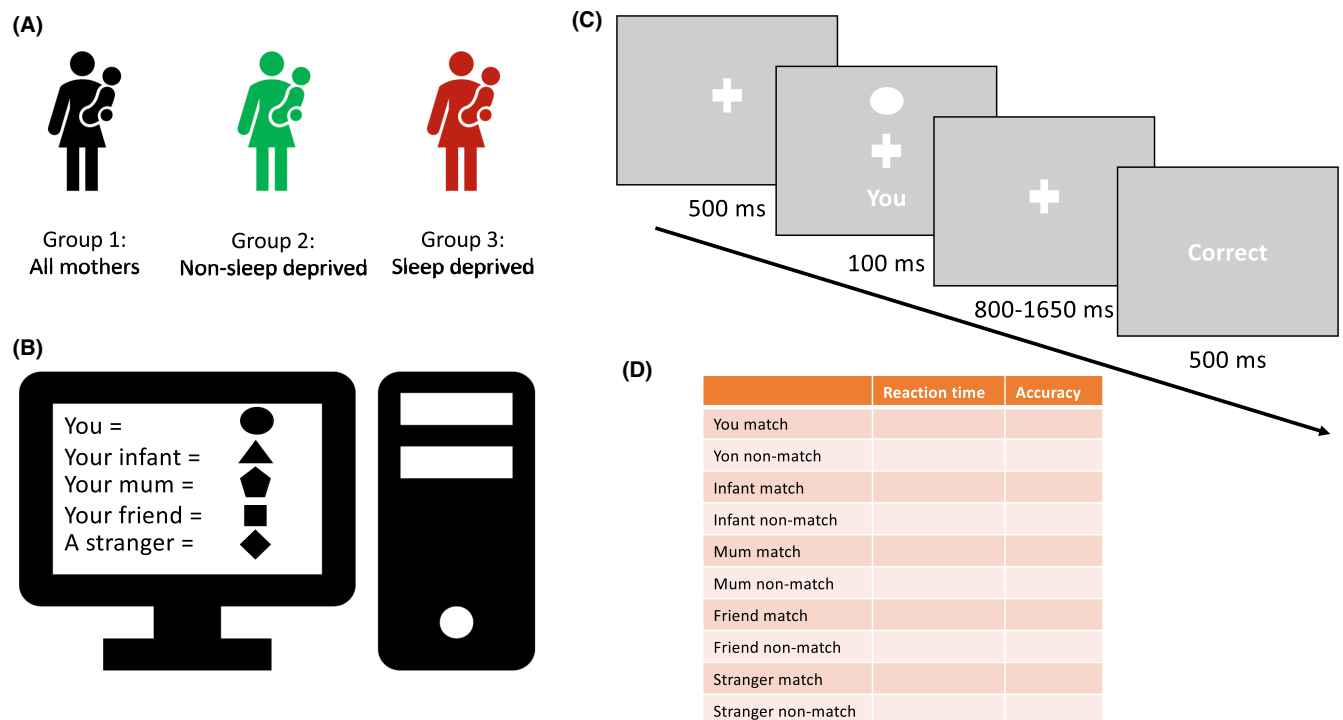
FIGURE 1 Overview of experimental design and groups 1–3. (A) Representation of the three groups. Group 1 consisted of all mothers disregarding the amount of total night-time sleep. Group 2 was the non-sleep-deprived group. Group 3 was the sleep-deprived group. (B) First, the participants were given a few minutes to learn the label-shape pairings, for example, "you are represented by a circle, your infant by a triangle, etc." (C) Next, the participants went through a practice round of 20 trials before the actual experiment started. When the experiment started, the participants saw a white fixation cross in the centre of the screen for 500 ms, followed by the pairing which appeared for 100 ms. After the stimulus, the participants had 800–1650 ms to respond. For 500 ms after their response, the result would appear on the screen showing whether the response was correct, false, or too slow. Then, the next trail started. (D) The reaction time and accuracy were extracted for both matched and non-matched trials resulting in 10 categories in total as demonstrated in the figure. Matched means that the shape-label pairing was correct (for instance the label you displayed with a circle). Non-matched means that the shape-label pairing was incorrect (for instance the label you displayed with a pentagon).

Since the data were not normally distributed, all 10 groups were bootstrapped. Normality tests were completed using the following tests with α 0.05: Anderson-Darling test, D'Agostino & Pearson test, Shapiro–Wilk test and Kolmogorov–Smirnov test. All the tests were performed using GraphPad Prism 9.2.0 (283) for Mac OS GraphPad Software (www.graphpad.com[20]).

Scatterplots and the bootstrapped mean, standard error of the mean and 95% confidence intervals were all done using MatlabR2016 while forest plots were made in Microsoft@ Excel for Mac, Version 16.54. p values were calculated using Mann–Whitney U-tests in MatlabR2016 on raw data.

Actigraphy data were analysed using the GGIR package version 2.4-0 in R version 3.6.1. The GGIR package is a standardised tool for actigraphy analysis,[21,22] Please see Actigraphy Settings page 6 in Appendix S1 for details on settings. To get a better average of the habitual night-time sleep duration (Total Sleep Time, night) of the participants, the sleep log data were added to the analysis of actigraphy data as guidance for the period of time in bed. The mean total

(A) All new mothers
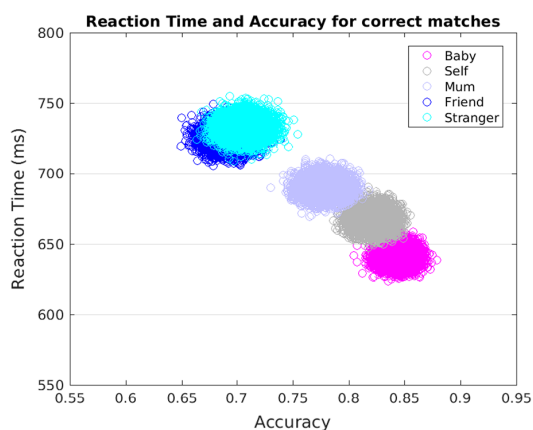
(B) Mothers sleeping more than 7 hours
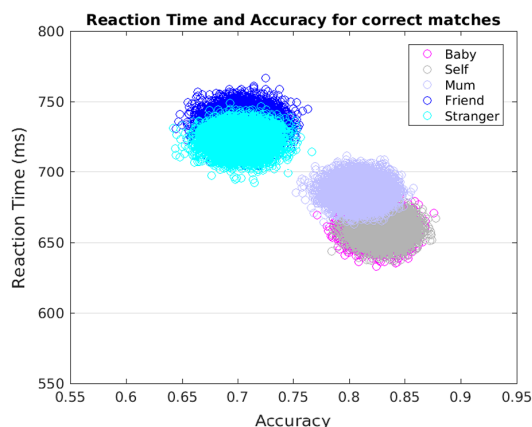
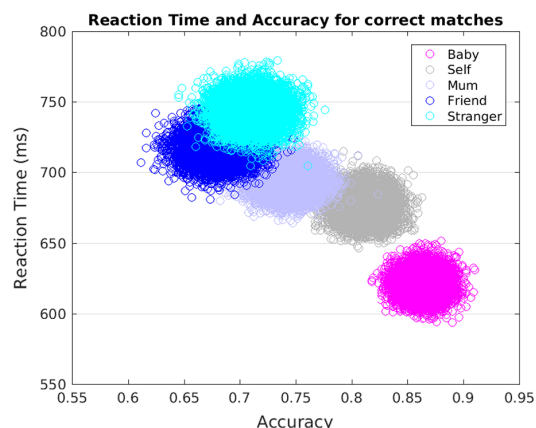**(C)** Mothers sleeping less than 7 hours

FIGURE 2 Infant prioritisation was strongest in sleep-deprived mothers. (A) Scatterplots for all the new mothers. Reaction time and accuracy of the bootstrapped data sets for the five categories: infant, self, mum, friend, stranger. Notice the slight overlap between infant and self (in the lower right corner). (B) Scatterplots for the new mothers with a total night-time sleep above 7 h. Notice the complete overlap between infant and self. (C) Scatterplots for the new mothers with a total night-time sleep below 7 h. Notice the infant category had the highest accuracy and lowest reaction time).

night-time sleep duration per week was averaged together for the 2 weeks. We did not find any statistically significant differences between the first and second week of total night-time sleep duration.

For participants who had only 1 week of actigraphy measurements the average of that week was used.

3 | RESULTS

All three groups are represented with scatterplots of accuracy as a function of reaction time for every category in the matched data sets in Figure 2. The scatterplot demonstrates an infant-prioritisation trend for all new mothers. The mothers who slept more than 7 h per night, with a mean of $7.68\,h \pm 0.40$ h, displayed equal self and infant prioritisation. Meanwhile, the mothers who slept <7 h per night, with a mean of $6.39\,h \pm 0.77$ h, clearly demonstrated an infant-prioritisation effect. This was both demonstrated with faster reaction times and higher accuracy in the infant category than in any other category (Figure 2).

There were no significant differences between the non-matched data sets, apart from in the self and stranger category in the non-sleep-deprived group; hence, these will not be presented in this study. For details on non-matched data sets, refer Appendix S1, page 2. For details on the mean, standard error of the mean and 95% confidence intervals of matched data sets, see Appendix S1, page 3.

For each of the categories in all three groups, we constructed forest plots of the mean and 95% confidence intervals for a visualisation of the significant results as can be seen in Figure 3. The forest plots show a consistent friend-stranger cluster with significantly lower accuracy and longer reaction time than the other three categories in all three groups. Self, mum and infant are creating different clusters either together or by themselves in the three different groups. Interestingly, the mothers who were not sleep deprived showed an equal self and infant prioritisation both regarding accuracy and reaction time, while the sleep-deprived mothers showed a clear infant prioritisation both in accuracy ($p = 0.005$) and reaction time ($p < 0.001$).

Finally, when the reaction times for the two groups were compared, it was clear, that the sleep deprived mothers had the fastest reaction time of all in the infant category ($p < 0.001$), with a mean reaction time of 621.22 ms (606.48–636.82), compared to the non-sleep-deprived group with a reaction time of 659.03 ms (646.44–672.04). This was also reflected in the overall data set including all participants, where there was no significant self or infant prioritisation regarding accuracy, but a significant infant prioritisation regarding reaction time.

4 | DISCUSSION

The results showed that sleep-deprived first-time mothers focused more on the infant than on themselves compared to matched first-time mothers without sleep deprivation. This provides evidence for an evolutionary survival of the species hypothesis, where the well-being of the infant overrules all other concerns when the mother is in a distressed state such as sleep deprivation.
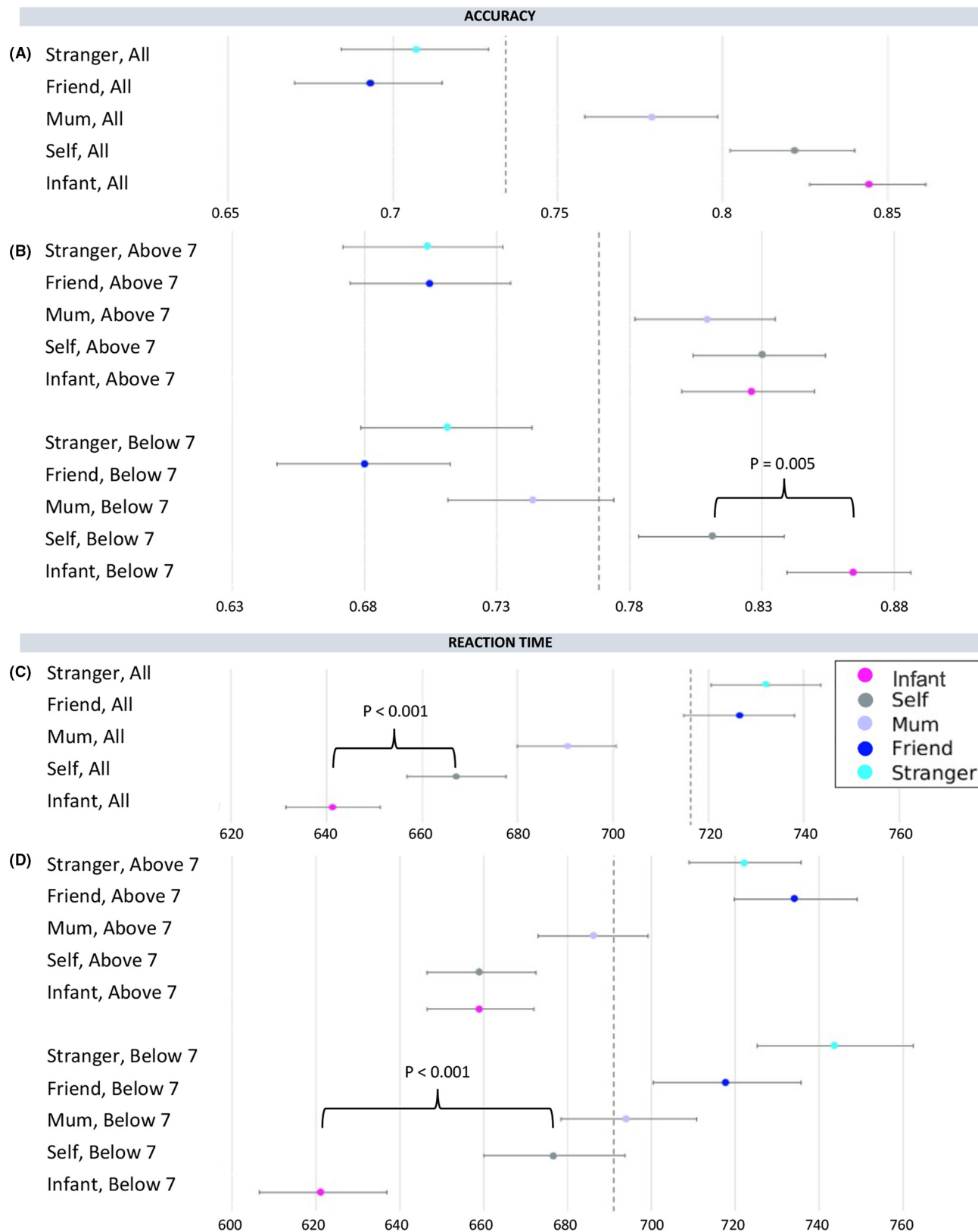
FIGURE 3 Forest plots for all three groups. Forest plot, for all new mothers, of the mean and 95% confidence intervals for accuracy (A+B) and reaction time (C+D). (A+B) Notice there was no statistically significant difference in accuracy between infant and self for all new mothers and the non-sleep-deprived mothers (Above 7), while there was a significant infant prioritisation for sleep-deprived mothers (Below 7). (C+D) Notice the significant infant prioritisation for all new mothers and the sleep deprived group (Below 7) compared to the equal self and infant prioritisation in the non-sleep-deprived group (Above 7). Furthermore, the fastest reaction time was seen for the sleep-deprived-mothers in the infant category.

When looking at the data for all 48 new mothers, there was no distinct self- or infant-prioritisation effect regarding accuracy, but a significant infant prioritisation regarding reaction time. These findings resemble results from previous research examining the change from self to infant prioritisation in first-time parents.[10]

When splitting the data according to sleep deprivation (average objective night-time sleep above or below 7h), the sleep-deprived group was significantly faster in the infant category than in any other category in both groups. This is a surprising result considering that sleep loss usually has been shown to prolong the reaction time,[23] and <7h of sleep per night for 14 days is found to increase the amount of attention lapses.[2,3] Importantly, this is a specific effect given that sleep deprivation is still driving an increase in attention lapses as shown by the lower number of total trials in the sleep-deprived group.

Please note that for the non-matched data sets, in accordance with previous research,[4,13,24] we did not find significant differences among the means of the different categories. However, for the self and stranger categories in the non-sleep-deprived group we found a statistically significant difference. This is most likely a type one error considering the results of previous research, but an alternative hypothesis could be that the increased level of rest enhances perception, thus creating a self-prioritisation effect in the non-matched data set. This seems likely, considering the decreased attention span seen during even low levels of sleep deprivation.[15]

With regards to our findings, one hypothesis for the results in the two groups of new mothers could be that the mothers who were not sleep-deprived were simply not as alert to the infant cues, such as crying as the sleep-deprived mothers and thus, did not wake up as often as the more sensitive mothers. If so, we would expect to find significant differences among the two groups in either the Postpartum Bonding Questionnaire or the Edinburgh Postnatal Depression Score, with mothers who were not sleep-deprived having a higher risk of impaired bonding or more severe symptoms of depression resulting in lower sensitivity towards infant cues. However, this was not the case, which is seen in Table 1.

An alternative explanation could potentially be found in the level of partner involvement. One might expect that the partners of the women in the non-sleep deprived group were more involved in the caregiving than the partners in the sleep-deprived group were. The increase in partner involvement could be a sign of early onset of postnatal depression, where the partner is taking over caregiving responsibilities as the mother is slowly withdrawing herself from the maternal role and perhaps changing from infant to self-prioritisation. Since psychiatric diseases are often followed by increased total sleep time,[25] this could explain the longer total night-time sleep duration observed in this group. We did not include data on partner involvement, but with no significant differences in Edinburgh Postnatal Depression Score among the two groups and the mean total night-time sleep being 7.68 ± 0.40 h, we do not find it likely that these women should be at increased risk of postnatal depression.

Hence, we hypothesise that the sleep-deprived mothers become more sensitive to infant cues due to the evolutionary importance of these cues, but further longitudinal studies examining both maternal sensitivity, sleep characteristics and the modified perceptual matching task are needed to understand the causality.

A potential limitation of this study was the late addition of the Postpartum Bonding Questionnaire and hence the incomplete data set. However, with a rather balanced distribution with 10 participants not filling out the Postpartum Bonding Questionnaire in both groups and no difference in Edinburgh Postnatal Depression Score scores between the two groups, it is unlikely that the difference in Postpartum Bonding Questionnaire would have reached significance with a full data set.

Another potential limitation of this study was the lack of pre-partum sleep measures. Theoretically, all the mothers in the sleep-deprived group could have been habitual short sleepers.[26] However, with the suggestion of increased attention lapses, this seems unlikely, but we suggest future studies to include pre-pregnancy and pre-delivery sleep measures as well. A further potential limitation of the study was the lack of data on household income and maternal smoking. However, people tend to select a partner with a similar socio-economic background,[27] and smoking is also linked to the socio-economic status.[28] Thus, with no significant difference between the two groups in educational level, we do not believe further data on income and smoking status would affect our results significantly. However this needs to be tested in future research.

Finally, we did not account for partner involvement, circadian rhythm or the ability to reflect on the child as a person with an individual mind, also known as mind-mindedness. Future research should take these factors into account.

5 | CONCLUSION

This study was the first to examine whether sleep disruption affects both the self- and infant-prioritisation effect in a population of first-time mothers within their first year of motherhood.

In contrast to mothers with no sleep deprivation who had no statistically significant difference between self and infant regarding both accuracy and reaction time, sleep-deprived mothers shifted from the well-known self-prioritisation towards infant prioritisation with statistical significance in both accuracy and reaction time. Furthermore, sleep-deprived mothers had a faster reaction time in the infant category compared to all the other categories in both groups. These findings showed that when cognitive resources are scarce in new mothers due to sleep deprivation, the prioritisation of infants becomes more important than herself.

CONFLICT OF INTEREST

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