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Early life experiences: Meaningful differences within and between families

Sophie von Stumm[a,*], Rachel M. Latham[b]

[a] Psychological and Behavioural Science, London School of Economics and Political Science, Houghton Street, WC2A NAE, London, UK
[b] Social, Genetic and Developmental Psychiatry Centre, King's College London, Institute of Psychiatry, De Crespigny Park, SE5 8AF London, UK

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ABSTRACT

Previous research has focused on differences in early life experiences that occur between families and their impact on children's development. However, less is known about the variations in early life experiences that occur *within* families. Here, 53 British mothers (mean age = 34.46 years; *SD* = 4.35) of newborn infants (mean age = 1.68 months, *SD* = 0.96) used a smartphone application (app) to repeatedly rate their wellbeing and support and to report their baby's and their own dietary and sleeping patterns (4 app alerts per week for 3 weeks; 12 assessments in total). We found that the app was a practicable tool for observing early life experiences, and that early life experiences differed on average to a greater extent within, rather than between families (59% versus 41% of the total variance). We also found preliminary evidence for meaningful associations among contemporaneous within-family variations in early life experiences.

1. Introduction

Early life experiences have pervasive long-term effects on children's psychological and behavioural development. Although early life experiences are likely to be too broad and too idiosyncratic to be captured and studied in full (Plomin & Daniels, 1987), key influences have been identified that shape children's developmental trajectories. They range from feeding practices for newborns (e.g. Victora et al., 2016; Yorifuji et al., 2014) to parents' child-directed language (e.g. Hart & Risley, 1995; Hoff, 2003) to families' socioeconomic status (SES; Bradley & Corwyn, 2002) and their wider neighbourhoods and local communities (e.g. Davis, Haworth, Lewis, & Plomin, 2012; Flouri, Midouhas, & Joshi, 2015). Associations between early life experiences and psychological and behavioural development become evident already in the first year of life (e.g. Hurt & Betancourt, 2017; von Stumm & Plomin, 2015).

Previous research on early life environments typically relied on one-time observer reports that are either collected from the parents (e.g. Haworth, Davis, & Plomin, 2013) or by trained researchers who visit the families' homes (e.g. Hart & Risley, 1995). For example, researchers or parents may complete the Confusion, Hubbub and Order Scale (CHAOS; Matheny, Wachs, Ludwig, & Phillips, 1995), which assesses the level of confusion and disorganization in the child's home environment and is recognized as a marker of family SES, or the Food Frequency Questionnaire (FFQ; e.g. Block et al., 1986) that obtains frequency and portion size information about people's food and beverage consumption. The scales are completed once in time for each family or study participant, under the assumption that they capture phenomena that are relatively static across time. A logical consequence of this measurement approach is focusing on differences in experiences that occur between families (e.g. Bradley & Corwyn, 2002; Hart & Risley, 1995), because within-family variations in early life experiences cannot be studied with one-time assessments.

* Corresponding author.
E-mail address: s.von-stumm@lse.ac.uk (S. von Stumm).

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Early life experiences emerge from the interplay of the physical and psychological environments that parents and other caregivers provide and the child's own psychological and behavioural function (Bronfenbrenner & Ceci, 1994). Because early life experiences are dynamic, developmental phenomena themselves, they do not vary exclusively between individuals or families. For example, a recent study of children's exposure to language in the family home found that the number of adult words that children heard over the course of a day varied as much within as between families (D'Apice & von Stumm, 2017), although previous research focused only on between-family differences in language exposure (e.g. Hart & Risley, 1995; Hoff, 2003). For the vast majority of the experiences that shape infants' early life development, the extent to which differences occur within compared to those between families is yet unknown. As a result, little attention has been paid to the effects of within-family variations on children's psychological and behavioural outcomes, while a large body of empirical evidence substantiates the role of between-family differences for development.

Studying within-family variations in early life experiences requires repeated assessments or observations that take place close in time to one another (i.e. hours or days). Traditional experience-sampling methods, like diary studies that ask participants to document either in paper-pen mode or through a computer survey their experiences as they go through life, are now common practice in many areas of developmental psychology (e.g. Hektner, 2012; Hoppmann & Riediger, 2009) but they are difficult to implement in families that look after a newborn, often in addition to caring for the baby's older siblings. However, these difficulties can be at least partly overcome through smartphone-based assessments that collect data with specifically designed applications (apps; Harari et al., 2016; Wrzus & Mehl, 2015). Today, 85% of British adults are estimated to own a smartphone (Deloitte, 2017), which offers an unprecedented opportunity to study psychological and behavioural phenomena in the wider population in real-time, including in infancy and early childhood.

The current study reports a preliminary test of using a smartphone app to observe across three weeks four key experiences that inform infants' early life, including mothers' and babies' sleep and dietary patterns, as well as mothers' wellbeing and the support that they receive as mothers. We focused on these four domains, because they (a) capture typical daily experiences in the lives of mothers and their babies, and (b) have been shown to affect children's developmental trajectories (e.g. Birch & Fisher, 1998; Davidson et al., 1998; Hiscock, Bayer, Hampton, Ukoumunne, & Wake, 2008; Muzik & Borovska, 2010). The aim of this research was threefold. First, we wanted to explore if smartphone apps are practicable for conducting experience-sampling studies with infants. To this end, we recruited a sample of mothers with infants aged 2 to 15 weeks to complete 12 app alerts over the course of three weeks. App alerts either assessed mothers' and babies' sleep and dietary patterns (3 times per week; 9 assessments overall), or mothers' wellbeing and support that they received (once per week; 3 assessments overall). Afterwards, mothers reported any difficulties, likes and dislikes they had experienced when using the app. Second, we sought to test the extent to which early life experiences varied within compared to between families. Specifically, we estimated within- and between-family variances in mothers' dietary intake, including the consumption of fish, fruit, alcohol and dietary supplements, and in mothers' wellbeing, the support that they received, and their sleeping patterns. In addition, we tested within- and between-family differences in the number of times that babies were fed and how many hours they slept. These analyses explored if early life experiences varied within families and thus, should not be exclusively treated as between-family differences. Finally, we wanted to provide preliminary evidence for the hypothesis that within-family variations that occur across assessments are meaningfully associated with concurrent variations in mothers' and babies' psychological and behavioural outcomes. To reliably detect such coupling effects, at least 10 but preferably more repeated assessments are recommended (Wang & Grimm, 2012), suggesting that the current study is somewhat underpowered (i.e. maximum number of assessments was 9). We therefore tested two simple associations between the within-family variances, rather than modelling a more complex nexus of relationships. The first focused on the relationship between mothers' quality of sleep, the number of hours that they slept, and the number of times that they attended to their newborn infant during the night. Previous research has shown that the goodness of fit between mothers' and infants' sleep predicts maternal depression and attachment security (Newland, Parade, Dickstein, & Seifer, 2016), and that the frequency with which mothers attend to their babies informs their subjective sleep quality (Gress et al., 2010). Here, we predicted that mothers, who slept more hours and attended to their baby fewer times compared to other mothers (i.e. between-mother effects), would report better sleep quality. We also predicted that mothers would report better sleep quality on days when they had slept more hours and attended to their baby fewer times during the night compared to other days (i.e. within-mother effects). The second test focused on predicting babies' differences in the number of hours that they slept across assessments from the differences in mothers' sleep duration. Sleep has been shown to facilitate the consolidation of declarative memory in infants (Seehagen, Konrad, Herbert, & Schneider, 2015) and creates semantic knowledge from individual episodic experiences (Friedrich, Wilhelm, Born, & Friedrich, 2015). In short, infants' sleep appears to be a key influence for their brain development and learning. We predicted that babies, whose mothers reported sleeping for longer durations, would also have slept longer hours than babies of mothers who had slept fewer hours (i.e. between-family difference). In addition, we predicted that babies would have slept longer on days in which their mothers reported having slept more hours, compared to other days (i.e. within-family variations). Our study design does not allow inferring the direction of causation – it is just as plausible that mothers sleep longer on days that their babies sleep longer as vice versa – but serves merely as a proof of concept.

2. Method

2.1. Sample

Fifty-three mothers of infants (30 boys and 23 girls) completed all parts of this research. Mothers' ages ranged from 24.49 to 42.38 years (mean = 34.46 years; *SD* = 4.35 years), and their infants' ages ranged from 0.48 to 3.60 months (mean age = 1.7 months, *SD* = 0.96 months). All mothers were in a relationship (mean duration = 7.87 years; *SD* = 3.48 years; range 1–17 years); most were

married (77.36%); and all except one lived with their partner. Most mothers had one (N = 22) or two (N = 27) children living in the home; few (N = 4) had three children.

The majority of mothers (88.67%) had achieved an undergraduate qualification or higher, were full-time employed (N = 22) or a full time parent (N = 12). For annual gross household income mothers endorsed, on average, the category of '£50,000 – £60,000'. Most mothers were British nationals (N = 43), spoke English as their first language (N = 45) and had resided in the UK for an average of 27.62 years (SD = 9.67; range = 1–40 years). Of the mothers whose first language was not English, two reported as their first language Polish; one Swedish; one Japanese; one Italian; one French; one Bulgarian; and one Yoruba.

2.2. Measures

2.2.1. Demographics and socioeconomic status

In an initial online survey, mothers reported their age, relationship status, employment status, highest education qualification, household income, UK nationality, language spoken, size of the family home, and the number of children who lived in the home with them. Additionally, mothers completed the MacArthur Scale of Subjective Social Status (Adler, Epel, Castellazzo, & Ickovics, 2000) and reported on the degree of chaos in the home using the Confusion, Hubbub and Order Scale (CHAOS; Matheny et al., 1995). For the MacArthur Scale, mothers were asked to rate where in society they stood relative to others on a ladder with 10 rungs, with the top of the ladder representing are the people who are the best off, who have the most money, most education, and best jobs. The CHAOS consists of 15 items, rated on a 4 point scale (1 = 'very much like my home' to 5 = 'not at all like my home'); example items include 'We have a set routine at home, for example regular dinner and bed times' and 'You can't hear yourself think on our home'. Positively phrased items were reverse-coded and then responses to all items averaged to create a total score such that a higher score indicated higher levels of household chaos (alpha = .84). We z-transformed household income, highest education, overcrowding index (i.e. number of rooms / number of people living in the home), MacArthur Scale, and CHAOS scores, which inter-correlated on average at 0.32, before summing them to an overall SES index adjusted for the number of indicators available for each family.

2.2.2. Exit survey

After completing the study's 3 weeks course, mothers completed an exit survey, specifically designed for this study, to assess their experiences with the app. Items asked about (a) the app's ease of use, for example 'Did you struggle completing the app among your other day-today responsibilities?' and 'Did you find the app's questions clear and unambiguous?'; (b) the content of the app (e.g. 'Did you think the app's questions were relevant to your experiences as a mother?'); (c) whether mothers wanted to alter the app (e.g. 'Reduce the number of alerts?'); and (d) mothers' attitudes towards participating in future research (e.g. 'Would you agree to participate in a study that used our app but did not offer monetary compensation?'). Responses were given on 6-point scales (from 'very much' to 'absolutely not'). Mothers also wrote open comments on what they particularly liked/ disliked or enjoyed/found difficult about using the app, and if they had suggestions for improving the app.

2.2.3. App-based measures

2.2.3.1. Mother diet. Oriented on the classical Food Frequency Questionnaire (Block et al., 1986), mothers were asked (a) how many meal-sized portions of (i) oily fish, (ii) whitefish and (iii) shellfish they had eaten in the past 2 days, which were added to a total fish score; (b) how many units of alcohol they had consumed in the past 24 h; and (c) how many portions of fruit and of vegetables they had eaten in the past 24 h. Each item was presented with examples of a typical portion size and corresponding images (see Fig. 1). Additionally, mothers were asked whether they had taken any of the following dietary supplements in the past 24 h: fish oils, vitamin A, vitamin B12, vitamin C, vitamin D, calcium, iron, magnesium, iodine, or any other. These were added to a unit-weighted total dietary supplements score.

2.2.3.2. Mother sleep. Seven items assessed mothers' sleep, including 'At what time did you go to bed last night (please state the time that you got into bed. This may not be the time that you began 'trying' to fall asleep)' and 'At what time did you get up this morning (please state the time that you got out of bed for the day without any further attempt at sleeping)'. Responses for both were given on a 24-hour clock in 15-minute intervals. From these responses, time spent in bed was calculated. Mothers were also asked how many times they got up from bed during the night to attend to their baby (e.g. to comfort or feed); and how many hours they had slept overall since going to bed last night, including any naps taken during the day. Finally, to assess their sleep quality in the past 24 h, mothers were asked to rate (a) the quality of their sleep (responses given on a 5-point scale from 'very poor' (1) to 'very good' (5)); (b) whether they felt they had slept enough ('by far not enough' (1) to 'more than enough' (5)); and (c) how rested or refreshed they had felt for the day ('not at all (1) to 'very much' (5)). The items were averaged to create a sleep quality score such that a higher score reflected better sleep quality. Cronbach's alphas for sleep quality ranged between 0.83 and 0.92 across the 9 assessments.

2.2.3.3. Mother wellbeing. Three items assessed mothers' wellbeing, which were adapted from the Warwick-Edinburgh Mental Wellbeing Scale (Tennant et al., 2007): 'In the past 3 days, did you feel (i) optimistic about your baby's future, (ii) relaxed with your baby, (iii) confident as a mother?' For each item responses were given on a 5-point scale ('not at all' (0) to 'very much (4)). Responses were averaged with higher scores indicating higher levels of wellbeing. Cronbach's alphas were 0.74 in week 1, 0.70 in week 2, and 0.73 in week 3.

2.2.3.4. Mother support. Mothers reported on their experience of feeling supported with the following items: 'In the past 3 days did

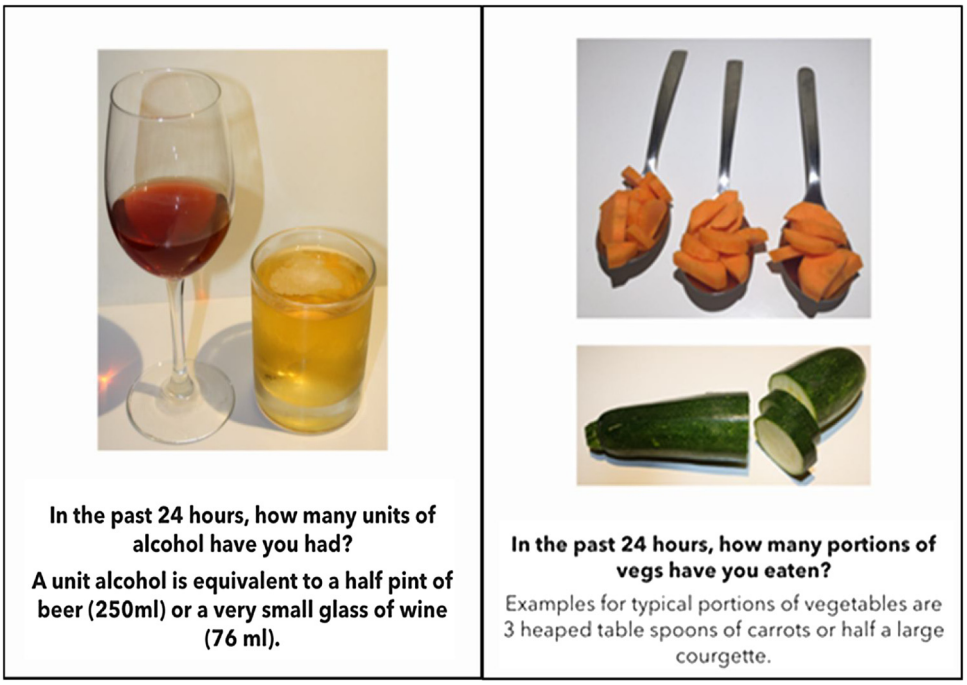

Fig. 1. Screen-shots from iPhone app illustrating two example items measuring mothers' diet.

you feel well supported as a mother by (i) your partner, (ii) your family, (iii) your friends, (iv) your employer/professional network, (v) social services, (vi) healthcare providers?' Responses for each were given on 5-point scale ('not at all' (0) to 'very much' (5) or 'does not apply'). Responses were averaged to create a total support score for each week.

2.2.3.5. Baby diet. Mothers reported the number of times they had fed their baby in the past 12 h (response options from 0 to 15), as well as up to 3 follow-up questions on how their baby was fed (e.g. breast-fed versus bottle-fed; fed by someone else) that are not reported here.

2.2.3.6. Baby sleep. One item measured baby's sleep, 'In the past 24 h, how many hours did your baby sleep? Please include in your estimate all the times your baby slept during the night and the day.' Response options from 0 to 24 hours were provided in 15-minute intervals.

2.3. Procedure

This study was reviewed by the Ethics Committee at Goldsmiths University of London and received ethical approval (project title: "Babygrow"). Participants were recruited via web, social media and flier advertisements. To be eligible, participants had to be the mother of a 2 to 15 week old infant and the owner of an iPhone (version 4 or later) on which they could download an app, which was specifically developed for this research and not freely available outside this study. Eligible mothers completed an online survey, which included demographic measures and background information on their own and their baby's diet and sleep. At the end of the survey they received a link to download and log in to the iPhone app using a secure password. Each week mothers then received 3 alerts (Mondays, Wednesdays and Saturdays at 5 pm) to complete a survey on their own and their baby's diet and sleep. Once a week (Thursdays at 11am) mothers received an alert to complete a survey on their wellbeing and experience of support. Each alert remained open until midnight of that day for mothers to respond and a reminder was sent every 2 h after the initial alert if a response was not received. At the beginning of each survey, mothers were asked how they and their baby were feeling today. Response options were given from 'extremely well' to 'very poorly'; if mothers responded 'very poorly' for either themselves or their baby, a follow-up question asked whether they and their baby feel well enough to complete today's survey. Mothers then could continue to the survey or opt out. Mothers were asked to complete the app for 3 consecutive weeks (i.e. each mother received 12 alerts), after which they completed an online exit survey regarding their experience of using the app. Mothers received a £50 shopping voucher for their participation.

3. Results

3.1. Practicability of smartphone app

A total of fifty-seven mothers completed the study's online survey and were eligible to participate in the app-based assessment. Two mothers did not download the app for unknown reasons, and another two were excluded from the analyses, because they did not complete the app alerts for the study duration of 3 weeks of the app alerts (i.e. 7% attrition). Of the 53 participating mothers, 39 (74%) completed the study's online exit survey. The majority of these mothers indicated that the app's questions were clear and easy to answer (82% of mothers agreed 'very much' or 'a lot' for both questions), and 79% said they looked forward to completing the app alerts.

More broadly, mothers' reported positive experiences from using the app for research on young infants. Most mothers found the app prompts neither too frequent nor stressful (85% 'not really' or 'absolutely not'), had no difficulties completing the app alongside their day-to-day responsibilities (70% 'not really' or 'absolutely not'), and almost all (95%) agreed that the app's questions were relevant to their experiences as a mother. Overall 67% of mothers indicated that they would participate in a future app-based study even without monetary compensation.

Mothers' open comments on the app suggested that responding to alerts had enhanced their awareness of their own behaviour, for example one mother said "Being asked about healthy eating is a good incentive to eat well", and another noted: "[The app] made me more aware of my diet and spurred me into eating more vegetables, sometimes going to bed earlier". They also reflected more on their baby's progress, for example one mother stated "[The app] made me realise my baby is sleeping for longer which was nice to know", and another observed "it was good for myself to keep an eye on my baby's sleep and feeds". Moreover, mothers also frequently commented on the ease of using the app (e.g. "It was easy and quick to use"; and "It's good it prompts you if you haven't responded").

Mothers' comments also highlighted their desire to receive feedback from and track their own app data, for example: "There is no way of tracking the data entered for my own viewing. As a user I'm not getting any feedback from it - just entering data. Therefore I'm not able to see changes/themes." Others suggested that feedback might be an incentive to engaging mothers with the app: "[The app alerts] seemed quite frequent but if I got feedback it might feel more worth completing regularly", and "It would have been great if I could have accessed/tracked the data […] for my own interest and this would have provided more incentive to carry on over a longer period without monetary incentive." Overall, these results support the practicability of using smartphones for collecting data on infant's early life experiences and highlight the need to develop adequate incentives.

3.2. Within- and between-family differences in early life experiences

To test the extent to which our measures of early life experiences varied within compared to between mothers, we computed intra-class correlations (ICC) using the R package ICC (version 2.3.0; update 2015-06-17; Wolak, Fairbairn, & Paulsen, 2012). Table 1 shows the within-mother means, standard deviations and ICCs for mother-reported measures of their baby's and their own dietary and sleeping patterns, as well as of their own wellbeing and support across assessments. Item level analyses and detailed results are reported in S1 through S6 in the Supplementary Materials for both mothers and babies. The ICCs ranged from 0.18 to 0.79 across measures, with a mean of .41, suggesting overall that on average more variance occurred within than between families. Mothers' support and use of dietary supplements were the most stable variables, with the majority of the variance occurring between families (i.e. 68% and 79%). By comparison, the hours of sleep and their consumption of fish varied most greatly within the mothers, with only 18% and 19% of the variance occurring between families.

Table 1
Aggregated within-mother means (*M*), standard deviations (*SD*) and intra-class correlations (ICC) across assessments.

		M	*SD*	ICC
Mother wellbeing[3]		3.25	0.50	0.52
Mother support[3]		2.61	0.48	0.68
Mother diet[9]	Fish [a]	0.60	0.65	0.19
	Fruit [b]	2.27	0.28	0.55
	Vegetables [b]	2.95	1.02	0.49
	Alcohol [c]	0.81	0.81	0.29
	Total dietary supplements [d]	1.71	0.69	0.79
Mother sleep[9]	Mother time spent in bed	8.65	4.85	0.18
	Mother hours asleep	6.28	3.17	0.55
	Frequency attending to baby	2.80	3.46	0.30
	Mother overall sleep quality	3.00	0.66	0.30
Mother on baby[9]	Baby feeds [e]	6.48	1.40	0.47
	Baby hours asleep	14.85	4.42	0.55

Note. [3] and [9] refer to the number of assessments completed for each variable complex. [a] portions consumed in past 2 days; [b] portions consumed in past 24 h; [c] units consumed in past 24 h; [d] amount taken in past 24 h; [e] number of feeds during past 12 h.

3.3. Testing associations of within- and between-family differences

We used mixed level modelling with the R package lme4 (version 1.1–17; update 2018-04-03; Bates, Maechler, Bolker, & Walker, 2015) to test associations between concurrent within-family differences in early life experiences. Because of our comparatively small sample size, we fitted separate models for each predictor and outcome variable set (i.e. 3 models overall). All variables were mean-centred; all models included fixed effects for mothers' and babies' age and the family SES as confounding variables. The first model defined mothers' quality of sleep as the dependent variable and the hours of sleep as the predictor across 9 assessment occasions. Fixed effects were modelled to capture the between-mother differences in the number of hours that they had slept. Random intercepts were specified for each mother and assessment time (level 1), in which random slopes were nested separately for the effect of the hours slept on the quality of sleep (level 2). Two further models were tested, with fixed and random effects specified as described above for the first model. The second tested the number of times that mothers attended to the baby during the night as the predictor of mothers' sleep quality. The third model linked babies' outcomes and mothers' experiences, by testing if babies' duration of sleep could be predicted from mothers' duration of sleep.

While *p*-values from *t*-statistics can be reported for fixed effects, the explanatory power of random effects can only be inferred from comparing the fits of baseline models without the random effects for within-mother differences in the hours of sleep and the times attending to the baby that affect the quality of sleep (Bates et al., 2015). Thus, we compared models with random effects in the hours of sleep and the times attending to the baby that affect the quality of sleep nested within mothers to models without these random effects, respectively. We applied a Bonferroni correction to our *p*-value to acknowledge that we tested two models in the same sample (conventional *p*-value of .05 divided by 2, resulting in $p = .025$).

Between-mother differences in the number of hours slept were positively associated with mothers' sleep quality across 9 assessments (i.e. fixed effects; $\beta = .37$, $SE = .04$, $t = 10.34$, $p < .001$), while differences in the times attending to the baby during the night were negatively associated ($\beta = -.22$, $SE = .02$, $t = -9.63$, $p < .001$), suggesting that mothers who slept longer hours and attended to their baby fewer times at night experienced a higher sleep quality than those who slept fewer hours and attended to their baby more often. Dropping the random slopes for the number of hours that mothers slept resulted in a significantly worse fitting model (χ^2 (4) = 42.35, $p < 0.001$), suggesting that in addition to the observed fixed effect, the effects of sleep duration varied meaningfully within mothers and assessment times. That is, mothers reported higher sleep quality on days when they slept more hours. By contrast, dropping the random slopes term for the times attending the baby during the night marginally affected the model fit (χ^2 (4) = 1.31, $p = .859$), suggesting that the effect of getting up on sleep quality did not vary within mothers across assessment times.

Babies' sleep duration was significantly predicted by between-mother differences in sleep duration ($\beta = .28$; $SE = .09$; $t = 3.26$; $p = .001$). After dropping the random slope terms from the model, the fit worsened significantly (χ^2 (4) = 11.91, $p = .018$). This finding suggests that babies slept longer on days on which their mothers also slept longer, compared to days when their mothers slept less. As stated above, the direction of causality is speculative and not proven. We re-ran all models without confounders; all findings were confirmed.

4. Discussion

Early life experiences, ranging from feeding practices in newborns to parents' child-directed language, have pervasive effects on children's psychological and behavioural development (e.g. Bradley & Corwyn, 2002; Hart & Risley, 1995). However, traditional research methods assessed early life experiences 'once in time' as static entities rather than as the dynamic processes that they are. As a result, much more is currently known about the developmental consequences of differences that occur between families than the variations that can be observed within families (Plomin & Daniels, 1987). Technological advances, such as smartphone apps, make it now possible to address this imbalance, because they help repeatedly observing typical family life in unobtrusive ways (Harari et al., 2016; Wrzus & Mehl, 2015). Although apps are already routinely used to collect data in other areas of psychology (e.g. von Stumm, 2018), the current study is a first attempt to test the practicability of apps for studying the dynamics of early life experiences in a sample of recent mothers and their babies.

Our study produced two key findings. First, the mothers in our sample reported they had no difficulties fitting the app use into their day-to-day lives to report on their own and their babies' status. Moreover, the majority of mothers enjoyed completing the app alerts and even identified intrinsic benefits, such as becoming more self-aware of their own and their baby's diet and sleep patterns. One challenge for future app-based research will be to find successful strategies for incentivising participants, particularly when monetary compensation is not available. Our finding that mothers wanted to use the app to better understand and monitor their babies' development suggests that personalised feedback may be a potential way to do this. Enabling mothers to view their own data and providing relevant information and interpretation may motivate individuals to participate – and remain engaged – in the research process. Overall, the mothers in our study confirmed that apps are practicable research tools for developmental psychology from the participants' perspective.

Our second finding corroborated the first from the researcher's point of view. The app's data suggested that early life experiences vary at least as much within as between families, suggesting that within-family differences are an important, yet currently overlooked area of research in developmental science (Plomin, 2011). Here, we also observed differences in the extent to which variances occurred within versus between families. For example, the number of mothers' dietary supplements differed mostly between (79%) but not within families (21%), suggesting that mothers take a fairly stable amount of dietary supplements across assessment occasions. By comparison, mothers varied greatly within themselves in the number of hours spent in bed across assessments, with the

majority of the variance occurring within (82%) rather than between families (18%). Although future research will have to replicate these differences in within- and between-family variance attributions and test if they are systematic and meaningful, we can conclude here that within-family variations in early life experiences are on average substantial.

Finally, we observed significant coupling effects between within-family variances in one variable and those in another, in addition to detecting significant associations among between-family differences. Specifically, we showed that mothers who slept more hours reported greater sleep quality than mothers who slept less (i.e. between-mother difference). More importantly, we also found that mothers reported higher sleep quality on days when they had slept more hours during the night (i.e. within-mother difference). Similarly, we showed that babies, whose mothers slept more hours, also slept longer (i.e. between-baby differences), in addition to sleeping longer on days when their mothers also slept for longer hours (i.e. within-baby differences). We acknowledge that these findings may be too obvious to justify empirical confirmation, but we reported them here to demonstrate that within-family differences in early life experiences can be systematically inter-related (cf. Gress et al., 2010). We caution that the direction of causality can only be inferred, not proven in our study design. We also note that no meaningful coupling effects were observed between within-mother variations in sleep quality and the frequency with which they attended to their baby. Because of our study's limited power, we refrain from interpreting this beyond the conclusion that not all variables' within-family variances are inter-related.

4.1. Limitations and future directions

Although our study has some notable strengths, including its innovative design, a specified sample that suits the research aims, and repeated assessments on reliable measures, it is also not without weaknesses. First, our dataset is too small to allow for a well-powered study on within- and between family differences, not necessarily because of the modest sample size (N = 53) but mainly because of the small number of assessments (at best 9) that is insufficient to reliably observe within-person changes over time (Wang & Grimm, 2012). Future research will have to develop strategies to successfully incentivise participants to contribute 10 and more repeated assessments, perhaps by giving personalised feedback based on participants' data, as suggested by our participants' qualitative feedback. A second limitation of our work is that we relied exclusively on mothers to report on their own and their babies' condition but no other family members, for example fathers, were assessed. Although parent reports are key to understanding early life environments, they suffer the same methodological limitations as other self-report or survey studies, for example social desirability and recall biases. However, smartphone technology enables collecting a wide range of data types that do not require self-report, for example sensor data through accelerometer and gyroscope readings, tracking of exercise, sleep and weight (i.e. wearables), and image-based information, such as videos and photographs. In addition, smartphone technology facilitates collecting data from multiple members of a family dyad, which will capture early life experiences in the family more comprehensively. Future research will have to explore and validate these alternatives to self-report measures, before they can be applied across different research settings and in clinical practice.

4.2. Conclusions

Developmental psychology's principal aim is to study the changes that we as individuals experience across the lifespan, including their causes and consequences. With previous research focusing almost exclusively on the developmental differences that occur between people, an incomplete understanding of the dynamics of experience has emerged. Change occurs between individuals, but also within themselves and their associated groups, such as family dyads. Going forward, developmental psychology will – assisted by new research technologies – transform our understanding of how and why we change within ourselves, including the role of early life experiences for our development.

Conflict of interest statement

We declare no conflict of interest with regard to this manuscript or the research described in it.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.infbeh.2018.09.001.

References

Adler, N. E., Epel, E. S., Castellazzo, G., & Ickovics, J. R. (2000). Relationship of subjective and objective social status with psychological and physiological functioning:

Preliminary data in healthy, White women. *Health Psychology, 19*, 586–592. https://doi.org/10.1037//0278-6133.19.6.586.
Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*, 1–48. https://doi.org/10.18637/jss.v067.i01.
Birch, L. L., & Fisher, J. O. (1998). Development of eating behaviors among children and adolescents. *Pediatrics, 101*, 539–549.
Block, G., Hartman, A. M., Dresser, C. M., Carroll, M. D., Gannon, J., & Gardner, L. (1986). A data-based approach to diet questionnaire design and testing. *American Journal of Epidemiology, 124*, 453–469. https://doi.org/10.1093/oxfordjournals.aje.a114416.
Bradley, R. H., & Corwyn, R. F. (2002). Socioeconomic status and child development. *Annual Review of Psychology, 53*, 371–399. https://doi.org/10.1146/annurev.psych.53.100901.135233.
Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nurture reconceptualized in developmental perspective: A bioecological model. *Psychological Review, 101*, 568–586. https://doi.org/10.1037/0033-295X.101.4.568.
D'Apice, K., & von Stumm, S. (2017). Early life language experience and intelligence. July *Paper Presented at the 17th Annual Meeting of the International Society for Intelligence Research*.
Davidson, P. W., Myers, G. J., Cox, C., Axtell, C., Shamlaye, C., Sloane-Reeves, J., ... Clarkson, T. W. (1998). Effects of prenatal and postnatal methylmercury exposure from fish consumption on neurodevelopment: Outcomes at 66 months of age in the Seychelles Child Development Study. *JAMA, 280*, 701–707. https://doi.org/10.1001/jama.280.8.701.
Davis, O. S., Haworth, C. M. A., Lewis, C. M., & Plomin, R. (2012). Visual analysis of geocoded twin data puts nature and nurture on the map. *Molecular Psychiatry, 17*, 867–874. https://doi.org/10.1038/mp.2012.68.
Deloitte (2017). *State of the smart: Consumer and business usage patterns. Global consumer survey 2017*. Retrieved fromUK Cut. London: Author. https://www.deloitte.co.uk/mobileuk/assets/img/download/global-mobile-consumer-survey-2017_uk-cut.pdf.
Flouri, E., Midouhas, E., & Joshi, H. (2015). Family and neighbourhood risk and children's problem behaviour: The moderating role of intelligence. *Intelligence, 53*, 33–42. https://doi.org/10.1016/j.intell.2015.08.003.
Friedrich, M., Wilhelm, I., Born, J., & Friedrich, A. D. (2015). Generalization of word meanings during infant sleep. *Nature Communications, 6*, 6004. https://doi.org/10.1038/ncomms7004.
Gress, J. L., Chambers, A. S., Ong, J. C., Tikotzky, L., Okada, R. L., & Manber, R. (2010). Maternal subjective sleep quality and nighttime infant care. *Journal of Reproductive and Infant Psychology, 28*, 384–391. https://doi.org/10.1080/02646831003727918.
Harari, G. M., Lane, N. D., Wang, R., Crosier, B. S., Campbell, A. T., & Gosling, S. D. (2016). Using smartphones to collect behavioral data in psychological science: Opportunities, practical considerations, and challenges. *Perspectives on Psychological Science, 11*, 838–854. https://doi.org/10.1177/1745691616650285.
Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children.* Baltimore, MD: Paul H. Brookes Publishing.
Haworth, C. M., Davis, O. S., & Plomin, R. (2013). Twins Early Development Study (TEDS): a genetically sensitive investigation of cognitive and behavioral development from childhood to young adulthood. *Twin Research and Human Genetics, 16*, 117–125. https://doi.org/10.1017/thg.2012.91.
Hektner, J. M. (2012). Developmental psychology. In M. R. Mehl, & T. S. Conner (Eds.). *Handbook of research methods for studying daily life* (pp. 585–600). New York, NY, US: Guilford Press.
Hiscock, H., Bayer, J. K., Hampton, A., Ukoumunne, O. C., & Wake, M. (2008). Long-term mother and child mental health effects of a population-based infant sleep intervention: Cluster-randomized, controlled trial. *Pediatrics, 122*, e621–e627. https://doi.org/10.1542/peds.2007-3783.
Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development, 74*, 1368–1378. https://doi.org/10.1111/1467-8624.00612.
Hoppmann, C. A., & Riediger, M. (2009). Ambulatory assessment in lifespan psychology: An overview of current status and new trends. *European Psychologist, 14*, 98–108. https://doi.org/10.1027/1016-9040.14.2.98.
Hurt, H., & Betancourt, L. M. (2017). Turning 1 year of age in a low socioeconomic environment: A portrait of disadvantage. *Journal of Developmental & Behavioral Pediatrics, 38*, 493–500. https://doi.org/10.1097/DBP.0000000000000469.
Matheny, A. P., Wachs, T. D., Ludwig, J. L., & Phillips, K. (1995). Bringing order out of chaos: Psychometric characteristics of the confusion, hubbub, and order scale. *Journal of Applied Developmental Psychology, 16*, 429–444. https://doi.org/10.1016/0193-3973(95)90028-4.
Muzik, M., & Borovska, S. (2010). Perinatal depression: Implications for child mental health. *Mental Health in Family Medicine, 7*, 239–247.
Newland, R. P., Parade, S. H., Dickstein, S., & Seifer, R. (2016). Goodness of fit between prenatal maternal sleep and infant sleep: Associations with maternal depression and attachment security. *Infant Behavior & Development, 44*, 179–188. https://doi.org/10.1016/j.infbeh.2016.06.010.
Plomin, R. (2011). Commentary: Why are children in the same family so different? Non-shared environment three decades later. *International Journal of Epidemiology, 40*, 582–592. https://doi.org/10.1093/ije/dyq144.
Plomin, R., & Daniels, D. (1987). Why are children in the same family so different from one another? *The Behavioral and Brain Sciences, 10*, 1–16. https://doi.org/10.1017/S0140525X00055941.
Seehagen, S., Konrad, C., Herbert, J. S., & Schneider, S. (2015). Timely sleep facilitates declarative memory consolidation in infants. *Proceedings of the National Academy of Sciences, 112*, 1625–1629. https://doi.org/10.1073/pnas.1414000112.
Tennant, R., Hiller, L., Fishwick, R., Platt, S., Joseph, S., Weich, S., ... Stewart-Brown, S. (2007). The Warwick-Edinburgh mental well-being scale (WEMWBS): Development and UK validation. *Health and Quality of Life Outcomes, 5*, 63. https://doi.org/10.1186/1477-7525-5-63.
Victora, C. G., Bahl, R., Barros, A. J. D., Franca, G. V. A., Horton, S., Krasevec, J., ... Rollins, N. C. (2016). Breastfeeding in the 21st century: Epidemiology, mechanisms, and lifelong effect. *Lancet (London, England), 387*, 475–490. https://doi.org/10.1016/S0140-6736(15)01024-7.
von Stumm, S. (2018). Feeling low, thinking slow? Associations between situational cues, mood and cognitive function. *Cognition & Emotion*. https://doi.org/10.1080/02699931.2017.1420632.
von Stumm, S., & Plomin, R. (2015). Socioeconomic status and the growth of intelligence from infancy through adolescence. *Intelligence, 48*, 30–36. https://doi.org/10.1016/j.intell.2014.10.002.
Wang, L., & Grimm, K. J. (2012). Investigating reliabilities of intraindividual variability indicators. *Multivariate Behavioral Research, 47*, 771–802. https://doi.org/10.1080/00273171.2012.715842.
Wolak, M. E., Fairbairn, D. J., & Paulsen, Y. R. (2012). Guidelines for estimating repeatability. *Methods in Ecology and Evolution, 3*, 129–137. https://doi.org/10.1111/j.2041-210X.2011.00125.x.
Wrzus, C., & Mehl, M. R. (2015). Lab and/or field? Measuring personality processes and their social consequences. *European Journal of Personality, 29*, 250–271. https://doi.org/10.1002/per.1986.
Yorifuji, T., Kubo, T., Yamakawa, M., Kato, T., Inoue, S., Tokinobu, A., ... Doi, H. (2014). Breastfeeding and behavioral development: A nationwide longitudinal survey in Japan. *The Journal of Pediatrics, 164*, 1019–1025. https://doi.org/10.1016/j.jpeds.2014.01.012.