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What factors influence dyadic synchrony? A systematic review of the literature on predictors of mother–infant dyadic processes of shared behavior and affect

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Abstract

Dyadic behavioral synchrony is a complex interactional process that takes place between the mother and her infant. In the first year of life, when the infant is prelinguistic, processes such as synchrony enable the dyad to communicate through shared behavior and affect. To date, no systematic review has been carried out to understand the risk and protective factors that influence behavioral synchrony in the mother–infant dyad. The aim of this review was to identify and evaluate the factors that influence behavioral synchrony in the mother–infant dyad, when the infant is between 3 and 9 months old. Key electronic databases were searched between 1970 and April 2021, and 28 eligible studies were identified for review. As the results were largely heterogeneous, four subgroups of factors were identified: (i) infant demographics, (ii) physiological factors, (iii) maternal mental health, and (iv) miscellaneous factors. Identified risk factors and covariates suggest that social determinants of health, underpinned by biological factors, play a large role in influencing behavioral synchrony within the dyad. Implications for the need to identify additional risk and protective factors, as well as design support for at-risk families are discussed.

KEYWORDS

dyadic processes, mother–infant interaction, synchrony

1 | INTRODUCTION

Early relationships are foundational in predicting a child's lifelong mental health and wellbeing, and a secure attachment between an infant and their primary caregiver has been shown to support emotional, cognitive, and social development throughout life (Kochanska, 2003; Meins, 1997). Numerous studies have shown that even before a baby can verbalize their needs and feelings, the ways in

which a mother and her prelinguistic infant communicate are essential for such a secure attachment (Isabella & Belsky, 1991; Meins et al., 2011; Stern, 1985). Responsive interactions within the mother–infant dyad have been shown to predict positive outcomes in developing language (Harrist et al., 1994) and empathy (Licata et al., 2016), and a number of seminal theorists have argued that attuned interactions between mother and infant are critical in developing the child's lifelong sense of self (Jonsson &

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Clinton, 2006; Winnicott, 1965), leading to improved mental health and relationships across the lifespan (Fonagy et al., 2004; Meins, 1997).

1.1 | Monadic and dyadic processes

Many authors have argued that maternal sensitivity, as well as maternal warmth and responsiveness are integral factors in developing effective communication between a mother and her child (Ainsworth et al., 1978; Bigelow et al., 2010), and maternal sensitivity during the first 6 months of life is a robust predictor of mother–infant attachment as the child develops (Bigelow et al., 2010). However, maternal sensitivity focuses solely on the actions and intentions of the mother, without considering the interactive behaviors or responses of the infant (Harrist & Waugh, 2002) and therefore constitutes a monadic process within the interaction of the dyad, neglecting to consider the dyadic processes that take place (Skuban et al., 2006).

The dyadic nature of mother–infant interactions has been well-documented. Trevarthen (1980) theorized that by 3 months of age, typically developing infants enter a developmental stage labeled “primary intersubjectivity”; defined as the developmental point at which infants begin to show an interest in and ability to communicate with humans around them. Empirical support from Feldman (2007) suggested that 3 months of age is a critical stage of development for infants as they begin to co-construct meaning within their early relationships. The dyadic nature of mother–infant interaction is also emphasized in several other developmental theories including affect attunement (Stern, 1985), maternal mind-mindedness (Meins et al., 2002), and mentalization and behavioral mirroring (Fonagy et al., 2004). These theories also highlight the importance of the timing and rhythm of the dyadic interaction, operationalized by Cohn and Tronick (1988) as the stochastic temporal organization of the dyad, with the implication that both partners are acting and reacting to the other’s behavior and affect.

1.2 | Dyadic behavioral synchrony

More recently, the dynamic systems approach has argued that mother–infant interactions are built through a mutually regulated process, likened to a bidirectional system wherein both partners play an important role in shaping the relationship (Beebe et al., 2016; Mantis et al., 2014). The concept of prelinguistic interaction as a bidirectional process is complex and nuanced, and it has been suggested that several different dyadic processes are simultaneously co-occurring including reciprocity (Feldman et al., 2012),

KEY FINDINGS

- Factors influencing dyadic behavioural synchrony can be categorised into four main categories: (i) infant demographics, (ii) physiological factors, (iii) maternal mental health, and (iv) a small number of miscellaneous factors.
- There was notable heterogeneity in the factors identified as influencing dyadic behavioural synchrony
- The review highlights that social determinants of health, underpinned by biological factors, can predict decreased synchrony in the mother–infant dyad.

STATEMENT OF RELEVANCE

This systematic review is the first to collate and synthesize the full range of factors identified as associated with mother–infant dyadic synchrony. By accurately identifying and understanding the factors influencing dyadic interaction, it may be possible to develop resources for support and education of at-risk families. This may further help optimize environments for sensitive interactions and psychological development.

mutual regulation (Van Egeren et al., 2001), self- and interactive contingencies (Beebe et al., 2016), and synchrony (Feldman, 2007; Field et al., 1989). Further nonlinear dynamic systems theory (Hollenstein, 2007) has suggested that the dyad is organized in such a way that both partners can move with flexibility into and between matched states of behavior as appropriate (Provenzi et al., 2015).

Among measures of coordinated dyadic behavior, the construct of synchrony is well-defined and historically validated. Dyadic synchrony has been observed in infants as young as 3 months old in various forms such as mutual gaze, facial affect, mutual touch, and complementary vocal interactions (Beebe et al., 2016; Cohn & Tronick, 1988; Feldman, 2007). In double video experimental studies, it has been indicated that infants as young as 2–4 months old can discern when an interaction has an asynchronous lag of just a couple of seconds and in noticing this, the infant will demonstrate fewer smiles and reduced periods of eye gaze towards their mother (Skotheim et al., 2013). In a recent systematic review, Provenzi et al. (2018, p.12) used computational text analysis to synthesize a broad

theoretical operationalization of the process, stating that synchrony is the “degree of congruence between transmodal behaviors of two partners, which is lagged in time and which promotes infants’ learning of emotional regulation skills and the emergence of expectations on interactive repertoires.” The implication of both partners leading and following each other in these ways is often described as a “dyadic dance” (Feldman, 2007; Provenzi et al., 2018), and in this way, synchrony is often thought of as the behavioral process that encompasses the more abstract concepts of mutuality and reciprocity (Harrist & Waugh, 2002; Provenzi et al., 2018). Due to this reciprocal and rhythmic nature of the dyad, synchrony has been implicated in the development of emotion regulation and empathy (Feldman, 2007), symbolic representation and understanding (Feldman & Greenbaum, 1998), and the emergence of turn-taking and interpersonal behaviors (Jaffe et al., 2001; Provenzi et al., 2018).

As with any system, a disruption in the interactive processes between a mother and her infant could lead to problems in the future, such as an increased potential for negative mental health outcomes across the lifespan. There are a number of identified risk factors, which could impact the effect of synchrony within the dyad. Maternal mood disorders such as anxiety and depression have been widely cited as predictors of problematic interactions between the mother and her infant (Beck, 1995; Feldman et al., 2009), and mothers with depressive symptoms spend less time in synchrony with their infant when measured for both gaze synchrony and verbal interaction (Feldman & Eidelman, 2007; Field et al., 1990). Indeed, maternal postnatal depression can present a serious risk to the development of the mother–infant interactive system, impacting on infant self-regulation in stressful situations (Granat et al., 2017). Conversely, mothers with anxiety have been shown to score higher for both gaze synchrony and touch synchrony than both depressed and control mothers (Granat et al., 2017). Research suggests that the higher levels of synchrony observed in anxious mother dyads are due to hypervigilant caretaking behaviors, which may lead to insecure-avoidant attachment styles (Malatesta et al., 1989; Beebe et al., 2008). Beebe et al. (2008) have, therefore, suggested that there is an optimal “midrange model” wherein the development of the infant is most benefitted.

Demographic risk factors such as socioeconomic status and maternal age may also impact on behavioral synchrony within the dyad, both as independent factors associated with dyadic synchrony (Hammer et al., 2019), and as potential covariates in mothers with mental health issues and other adversities (Tarullo et al., 2017). As families who are living in disadvantaged environments are likely to experience a compounding effect of socio-political health factors (Sameroff & Seifer, 1995), understanding the

accumulation of such risk factors is crucial in understanding how to support families most in need. However, to date, no review has systematically explored risk and/or protective factors of bidirectional behavioral synchrony in the mother–infant dyad for infants aged between 3 and 9 months old. This is of particular importance, given that this developmental period can be considered to be pivotal to developing primary intersubjectivity.

Consequently, the primary aim of this review was to identify, summarize, and evaluate any factors that have been shown to impact behavioral synchrony within the mother–infant dyad when the child is between 3 and 9 months old, in the first stages of developing intersubjectivity with other individuals. Further, we intended to identify characteristics of the studies, including the procedures and coding schemes that are employed in measuring dyadic behavioral synchrony. Finally, we sought to critically evaluate the quality, and risk of methodological bias, of the existing literature.

2 | METHODS

This systematic review was conducted following the PRISMA guidelines (Page et al., 2021), utilizing the PRISMA-P (Moher et al., 2015) and PRISMA-S (Rethlefsen et al., 2021) extensions. Prior to conducting the systematic search, a search protocol was designed, piloted, and subsequently registered on PROSPERO (registration number CRD42021233187).

2.1 | Inclusion and exclusion criteria

Eight inclusion criteria were applied to the literature in order to identify articles for the review. These criteria comprised papers that reported original primary data from observational studies, as well as identifying behavioral synchrony as the measured outcome. Thirdly, it was necessary that the papers measured the effect of an identified factor on behavioral synchrony, and that they included measures of dyadic synchrony within the coding scheme. An age range was applied to the search, and papers that contained a population sample of children aged between 3 and 9 months (i.e., within the stage of primary intersubjectivity) and their mother were included. A study would be considered for inclusion if the sample population included infants aged 2 or 10 months, but the mean age was still between 3 and 9 months. Additionally, included papers needed to present statistical data on the strength of association between the identified factor and behavioral synchrony, should be written in English, and published between 1970 and April 2021. This time period was chosen

as developmental theories relating to dyadic processes of mother–infant interaction were mainly advanced after 1970.

Exclusion criteria comprised articles that did not present primary data, and did not include observational measures of dyadic synchrony in the coding scheme. Additionally, papers that measured dyadic synchrony but the dyad was not mother–infant were excluded, as well as those that presented findings on nonhuman populations, single case studies, or were unpublished articles, including unpublished studies, dissertations, or conference abstracts.

2.2 | Literature search

Potentially relevant studies were initially identified by electronic database search of PubMed (MEDLINE), Embase (1974 to 2021 April 30), and Web of Science, as well as the first 200 results retrieved from Google Scholar (this approach was reported as optimal for potential retrieval rates in a systematic review by Bramer et al. (2017)). The search terms “(Mother) AND (Infant OR Baby) AND (Synchrony)” were developed with the assistance of a specialist librarian after an initial scoping review and pilot searches, and the same search string was used across all four databases. Within the search filters, the language was limited to English and the years of publication were limited from 1970 to 2021. This timeframe was considered relevant to when theories regarding attachment and mother–infant relationships were being advanced amongst developmental theorists. After compiling the results using EndNote X9, duplicates were removed, and inclusion and exclusion criteria were applied to the remaining titles and abstracts. Full texts of studies that potentially fitted inclusion criteria were reviewed against these criteria by two independent reviewers. Further to database searches, the reference lists of all included studies were then surveyed to identify any papers that may have been missed in the original computerized search. To ensure that inclusion criteria were met, a table was created to aid with data extraction. This table allowed the reviewers to independently document for each study the age of the participants, the measured outcome of the study, the measure of dyadic synchrony and coding scheme used, as well as a space for additional notes. The papers were then coded green for included, red for excluded, and orange if further discussion was needed. This color coding scheme was used to understand the initial levels of interrater agreement at this stage. If consensus was not reached between the two reviewers concerning the final inclusion of a paper, it was discussed with the remaining authors for resolution. For details of the search process see (Figure 1) PRISMA flowchart (Haddaway & McGuinness, 2020).

2.3 | Outcomes

Outcomes were characterized as any factor that showed an association with dyadic behavioral synchrony within the infant–mother dyad. It has been noted that measurements of synchrony are often closely related to the measurements of similar theoretical concepts, such as reciprocity, mutuality, and rhythmicity (Leclère et al., 2014). It has also been suggested that the definition of synchrony can be likened to the definitions of similar measurable constructs, such as mutual contingency, behavior state matching, and dyadic affect regulation, amongst others (Harrist & Waugh, 2002). For the purposes of this review, and in an attempt to achieve conceptual clarity, only studies that explicitly identified the measured construct as synchrony were included. Further, to ensure that the studies were measuring a bidirectional process of synchrony, it was also necessary that the authors had included measures of dyadic synchrony in their coding schema during observations. Significant associations were defined as having a *p* value of .05 or less.

2.4 | Critical evaluation and risk of bias

A critical evaluation was carried out on all included studies to assess for methodological risk of bias. This evaluation was carried out using an adapted version of the quality evaluation grid developed by Glod et al. (2015). This evaluation grid was chosen for use as it highlights the necessity of valid and reliable psychometric tools when measuring a variety of theoretical constructs. As the original grid was designed to be used for studies of constructs relating to autism and ASD, adaptations meant that 23 of the original 30 criteria were used for this evaluation. The evaluation grid is divided into four sections: introduction, with subsections pertaining to adequately described concepts, aims, and objectives; methods, concentrating on the reporting of inclusion and exclusion criteria, representative sampling, demographics, the measurement of identified factors, and the measurement of dyadic synchrony; results, with subsections for descriptive statistics, how statistical significance was determined, and the reporting of sufficient sample sizes and effect sizes; and discussion, rating the appropriateness of conclusions and limitations. The outcome of each criterion in the grid was entered in a scoring system, and assigned a rating from yes = 2, partially = 1, no = 0, or not reported = 0, allowing a range of scores from 0 to 46. The evaluation grid was conducted independently by two reviewers. In order to differentiate between a yes and partial score, a yes had to be clearly evident to both reviewers. Where there was possible evidence of a yes but this was not clear to one or both reviewers then a score of partial was given. The

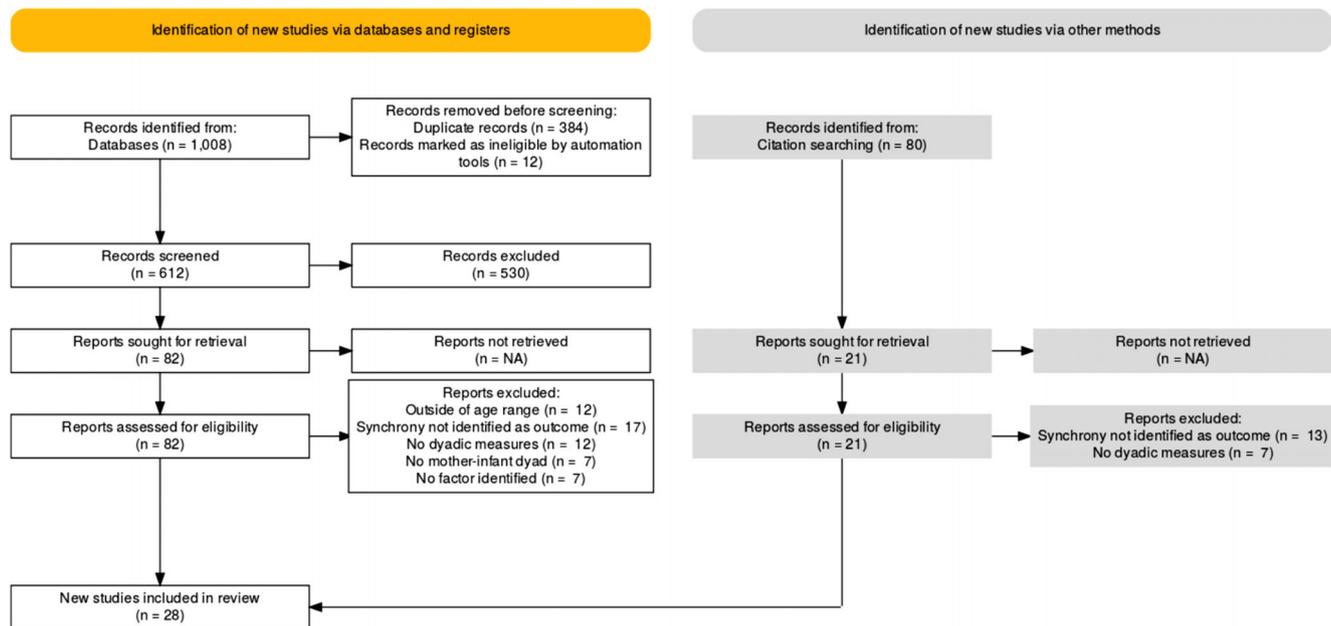


FIGURE 1 PRISMA flowchart

overall interrater reliability was $\kappa = .72$, indicating substantial agreement. Major discrepancies between the scores were discussed and resolved by consensus, and the process was overseen by the remaining authors, although these authors were not directly involved in the critical evaluation process.

3 | RESULTS

In total, 28 papers were included in the final review. Characteristics of all studies are detailed in Table 1. All studies used primary data and a prospective cohort design. The 28 studies represented 27 different sample populations, with two studies from Germany (Lotzin et al., 2015; Lotzin et al., 2016) utilizing the same sample but examining different risk factors. Hereafter, these two study records will be combined and considered as one study (cited as Lotzin et al., 2015). The remaining 26 papers included 13 studies from the United States (Busuito et al., 2019; Coburn et al., 2015; Field et al., 1989, 1990; Lester et al., 1985; Moore & Calkins, 2004; Moore et al., 2016; Tarullo et al., 2017; Tronick & Cohn, 1989; Tuladhar et al., 2018; Weinberg et al., 1999, 2006, 2008); seven studies from Israel (Apter-Levi et al., 2014; Atzil et al., 2011; Feldman, 2006; Feldman & Eidelman, 2007; Gordon et al., 2017; Granat et al., 2017; Kaitz et al., 2010) and single studies originating from the Netherlands (de Graag et al., 2012), Denmark (Kristensen et al., 2017), Austria (Markova et al., 2020), Italy (Montirosso et al., 2010), and Australia (Penman et al., 1983). A final study (Gratier, 2003) recruited an interna-

tional sample from both France, the United States, and India.

3.1 | Sample population

The total population comprised $n = 2241$ mother–infant dyads ($k = 27$). Individual sample sizes ranged from $n = 10$ (Penman et al., 1983) to $n = 209$ (Kristensen et al., 2017). All infants in the studies ranged from 2 to 9 months old with the mean ages reported in studies ranging between 3 and 9 months old. For studies that reported infant gender ($n = 17$, where $n =$ number of cohorts reporting), 48% of the infants were female and 52% were male. Across the studies, mothers ranged in age from 14 to 41 years of age, although two studies did not report mothers' age (Gratier, 2003; Lester et al., 1985). Rate of primiparous birth was reported in 15 studies (Apter-Levi et al., 2014; Busuito et al., 2019; Field et al., 1989, 1990; Gordon et al., 2017; Granat et al., 2017; Gratier, 2003; Kaitz et al., 2010; Kristensen et al., 2017; Lotzin et al., 2015; Markova et al., 2020; Moore et al., 2016; Penman et al., 1983; Weinberg et al., 1999, 2006). Where parity was reported, the percentage of first-born infants included in studies ranged from 44% to 100%.

3.2 | Observational procedures and measures of synchrony

In order to observe the infant–mother dyad interaction, 15 studies recorded mothers and infants during a face-to-face

TABLE 1 Characteristics of included studies

Authors, year, location	Infant sample; N, age, gender	Mother sample; N, age, parity	Observational procedure	Coding scheme	Impacting factors identified
Apter-Levi et al., 2014 Israel	N = 71 4–6 months n/a	N = 71 28.9 years (SD = 5.2) 55% primiparous	Face-to-face interaction	Gaze synchrony (Feldman & Eidelman, 2004)	Oxytocin Vasopressin
Atzil et al., 2011 Israel	N = 28 4–6 months n/a	N = 28 22–37 years n/a	Face-to-face interaction	Maternal synchrony (Feldman & Eidelman, 2004)	Oxytocin
Busuito et al., 2019 USA	N = 140 6 months 43% F/57% M	N = 140 32 years (SD = 1.7) 57.6% primiparous	FFSF	Monadic phases (Tronick et al., 1982)	SNS PNS RSA (PNS index) Skin conductance (SNS index) Heart period (SNS & PNS index)
Coburn et al., 2015 USA	N = 205 3 months n/a	N = 205 27.8 years (SD = 6.5) n/a	Teaching task	CIB (Feldman, 1998)	Depression Daily life hassles Stress
de Graag et al., 2012 The Netherlands	N = 84 5 months 45% F/55% M	N = 84 32.5 years (SD = 3.9) n/a	Modified FFSF	Gaze synchrony	Infant sleep
Feldman, 2006 Israel	N = 71 3 months n/a	N = 71 28.8 years (SD = 6.1) n/a	Face-to-face interaction	Monadic phases (Tronick et al., 1980)	Premature birth Infant physiological measures Infant sleep
Feldman & Eidelman, 2007 Israel	N = 108 3 months 46% F/54% M	N = 108 29.5 years (SD = 5.8) n/a	Face-to-face interaction	Gaze synchrony (Feldman & Eidelman, 2004)	Premature birth Maternal depression Maternal behavior Infant vagal tone
Field et al., 1989 USA	N = 16 3 months n/a	N = 16 18–33 years 100% primiparous	Face-to-face interaction	Behavior state coding (Cohn et al., 1986)	Maternal depression
Field et al., 1990 USA	N = 48 3.4 months n/a	N = 48 14–41 years 81% primiparous	Face-to-face interaction	Behavior state coding (Cohn et al., 1986)	Maternal depression

(Continues)

TABLE 1 (Continued)

Authors, year, location	Infant sample; N, age, gender	Mother sample; N, age, parity	Observational procedure	Coding scheme	Impacting factors identified
Gordon et al., 2017 Israel	N = 80 6 months 46% F/54% M	N = 80 27.7 years (SD = 3.5) 100% primiparous	Face-to-face interaction	Parent-Infant synchrony (Feldman & Eidelman, 2007)	Testosterone Oxytocin
Granat et al., 2017 Israel	N = 100 9 months 47% F/53% M	N = 100 30.7 years (SD = 3.4) 45% primiparous	Face-to-face interaction	Synchrony Coding Scheme (Feldman, 2002)	Maternal depression Maternal anxiety
Gratier, 2003 France/USA/India	N = 60 2–5 months 55% F/45% M	N = 60 n/a 100% primiparous	Face-to-face interaction	Acoustic analysis	Immigrant experience
Kaiz et al., 2010 Israel	N = 93 6 months 54% F/46% M	N = 93 25.5 years (SD = 4) 100% primiparous	-Face-to-face interaction -Teaching task	- ICEP (Weinberg & Tronick, 1999) - RSIS (Clark & Seifer, 1983)	Maternal anxiety disorders
Kristensen et al., 2017 Denmark	N = 209 2–6 months 62% F/38% M	N = 209 30.2 years (SD = 5) 98% primiparous	Face-to-face interaction	CARE-Index (Crittenden, 2006)	Video feedback intervention (low confidence, postnatal depression, premature birth)
Lester et al., 1985 USA	N = 40 3–5 months n/a	N = 40 n/a n/a	Face-to-face interaction	Monadic phases (Tronick et al., 1980)	Premature birth
Lotzin et al., 2015, 2016 Germany	N = 68 4–9 months 43% F/57% M	N = 68 32.3 years (SD = 5.4) 83.8% primiparous	FFSF	- MRSS (Tronick & Weinberg, 1990) - IRSS (Tronick & Weinberg, 1996) - Facial Affect Rating Scale (Beebe et al., 2010)	Maternal mood disorder Maternal emotion regulation
Markova et al., 2020 Austria	N = 56 4 months 50% F/50% M	N = 56 31 years (SD = 3.5) 92.1% primiparous	Face-to-face interaction	Gaze synchrony/Affect synchrony (Feldman et al., 2011)	Maternal playful singing
Montirosso et al., 2010 Italy	N = 50 6.8–9.9 months 46% F/54% M	N = 50 33 years (SD = 4.7) n/a	FFSF	ICEP (Weinberg & Tronick, 1999)	Premature birth
Moore & Calkins, 2004 USA	N = 73 3 months 41% F/59% M	N = 73 29.1 years (SD = 5.4) n/a	FFSF	Monadic phases (Tronick et al., 1980)	Infant vagal regulation

(Continues)

TABLE 1 (Continued)

Authors, year, location	Infant sample; N, age, gender	Mother sample; N, age, parity	Observational procedure	Coding scheme	Impacting factors identified
Moore et al., 2016 USA	N = 75 6 months 41% F/59% M	N = 75 32.3 years (SD = 4.4) 66.7% primiparous	FFSF	Monadic phases (Tronick et al., 1980)	Maternal anxiety during pregnancy
Penman et al., 1983 Australia	N = 10 3 months n/a	N = 10 17–30 years 100% primiparous	Face-to-face interaction	Behavioral modalities (Tronick et al., 1977)	Neonatal physiological measures (BNBAS)
Tarullo et al., 2017 USA	N = 121 5.8–7.5 months 49% F/51% M	N = 121 33.4 (SD = 4) n/a	Face-to-face interaction	Positive Engagement Synchrony (Feldman et al., 2011)	Maternal chronic stress
Tronick & Cohn, 1989 USA	N = 54 3, 6, and 9 months “balanced”	N = 54 n/a n/a	Face-to-face interaction/FFSF	Monadic phases (Tronick et al., 1980)	Infant age and gender
Tuladhar et al., 2018 USA	N = 73 6 months 50% F/50% M	N = 73 33.6 years (SD = 3.8) n/a	Face-to-face interaction	Positive engagement synchrony (Feldman et al., 2011)	Maternal perception of how they were parented
Weinberg et al., 2008 USA	N = 94 3 months 53% F/47% M	N = 94 34 years (SD = 3) n/a	FFSF	–MRSS (Tronick & Weinberg, 1990) –IRSS (Tronick & Weinberg, 1996)	Maternal depression Maternal panic disorder
Weinberg et al., 2006 USA	N = 133 3 months 48% F/52% M	N = 133 21–40 years 100% primiparous	FFSF	AFEX system (Izard & Dougherty, 1980)	Maternal depression
Weinberg et al., 1999 USA	N = 81 5–6 months 53% F/47% M	N = 81 20–39 years 44% primiparous	FFSF	–MRSS (Tronick & Weinberg, 1990) –IRSS (Tronick & Weinberg, 1996) –AFEX system (Izard & Dougherty, 1980)	Infant gender

Abbreviations: BNBAS, Brazelton Neonatal Behavioral Assessment Scale; CARE-Index, Child-Adult Relationship Experimental Index; CIB, Coding Interactive Behavior global coding system; EAS, Emotional Availability Scales; FFSF, Face-to-face still-face paradigm; ICEP, infant and caregiver engagement phases; IRSS, Infant Regulatory Scoring System; MRSS, Mother Regulatory Scoring System; PNS, parasympathetic nervous system; RSA, respiratory sinus arrhythmia; RSIS, Rating Scale of Interactional Style; SNS, sympathetic nervous system.

interaction procedure (Apter-Levi et al., 2014; Atzil et al., 2011; Feldman, 2006; Feldman & Eidelman, 2007; Field et al., 1989, 1990; Gordon et al., 2017; Granat et al., 2017; Gratier, 2003; Kristensen et al., 2017; Lester et al., 1985; Markova et al., 2020; Penman et al., 1983; Tarullo et al., 2017; Tuladhar et al., 2018). An additional eight studies used a Face-to-Face Still-Face (FFSF) paradigm procedure (Busuito et al., 2019; Lotzin et al., 2015; Montiroso et al., 2010; Moore & Calkins, 2004; Moore et al., 2016; Weinberg et al., 1999, 2006, 2008) as well as one modified FFSF paradigm (de Graag et al., 2012). In one study, a face-to-face interaction as well as a teaching task were employed (Kaitz et al., 2010); in another study, a face-to-face interaction was supplemented with a FFSF paradigm (Tronick & Cohn, 1989), and a further study employed a teaching task as the observational procedure (Coburn et al., 2015).

Several coding schemes were applied to measure the dyadic synchrony between mother and infant including nine studies employing micro-analytical coding schemes (Apter-Levi et al., 2014; Atzil et al., 2011; de Graag et al., 2012; Feldman & Eidelman, 2007; Gordon et al., 2017; Granat et al., 2017; Markova et al., 2020; Tarullo et al., 2017; Tuladhar et al., 2018) and a further study employing the “Coding Interactive Behavior” (CIB; Feldman, 1998) scale (Coburn et al., 2015). Additional scales used “Monadic Phases” (Tronick et al., 1982) employed in six studies (Busuito et al., 2019; Feldman, 2006; Lester et al., 1985; Moore & Calkins, 2004; Moore et al., 2016; Tronick & Cohn, 1989); both the “Mother Regulatory Scoring System” (MRSS; Tronick & Weinberg, 1990) and the “Infant Regulatory Scoring System” (IRSS; Tronick & Weinberg, 1996) were used in conjunction in three studies (Lotzin et al., 2015; Weinberg et al., 2008; Weinberg et al., 1999); “Behavior State Coding” (Cohn et al., 1986) utilized in two studies (Field et al., 1989, 1990); the “Infant and Caregiver Engagement Phases” (ICEP; Weinberg & Tronick, 1999) used in two studies (Kaitz et al., 2010; Montiroso et al., 2010); and the AFFEX system (Izard & Dougherty, 1980) also used in two studies (Weinberg et al., 1999, 2006). Other coding schemes employed in single studies were acoustic analysis (Gratier, 2003), the “Child-Adult Relationship Experimental Index” (CARE-Index; Crittenden, 1981; Kristensen et al., 2017), the “Facial Affect Rating Scale” (Beebe et al., 2010; Lotzin et al., 2015), and “Behavioral Modalities” (Tronick et al., 1982; Penman et al., 1983).

3.3 | Factors identified

Across the studies, a heterogeneous range of potential risk and protective factors were identified. For the purposes

of this review, the factors were clustered into four categories: (i) demographic factors, (ii) physiological factors, (iii) factors relating to maternal mental health, and (iv) miscellaneous factors.

Demographic factors identified included infant age (Tronick & Cohn, 1989) and infant gender (Tronick & Cohn, 1989; Weinberg et al., 1999). Studies exploring physiological factors were further subdivided into three subcategories including premature birth, infant physiological factors, and maternal biomarkers. The biomarkers examined included oxytocin (Atzil et al., 2011), oxytocin and vasopressin (Apter-Levi et al., 2014), and oxytocin and testosterone (Gordon et al., 2017). A further study investigated the impact of the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) (Busuito et al., 2019). Infant physiological factors included infant sleep (de Graag et al., 2012), infant vagal regulation (Moore & Calkins, 2004), and neonatal physiological measures (Penman et al., 1983). Four studies examined premature birth as a risk factor of subsequent dyadic synchrony (Feldman, 2006; Feldman & Eidelman, 2007; Lester et al., 1985; Montiroso et al., 2010).

Maternal mental health factors included three studies of depression diagnosed before pregnancy (Coburn et al., 2015; Field et al., 1989, 1990) and depression diagnosed before pregnancy compared to panic disorder (Weinberg et al., 2008). Additionally, two studies identified postnatal depression as a risk factor (Granat et al., 2017; Weinberg et al., 2006). Further studies identified risk factors such as anxiety disorder (Kaitz et al., 2010), mood disorders and emotion regulation (Lotzin et al., 2015), anxiety experienced during pregnancy (Moore et al., 2016), and chronic stress (Tarullo et al., 2017).

Additional miscellaneous factors identified include the experience of immigrant mothers (Gratier, 2003), maternal playful singing during face-to-face interactions (Markova et al., 2020), and mothers' perceptions of how they themselves were parented as children (Tuladhar et al., 2018). A final study developed and measured the effects of an intervention aimed at first-time mothers (Kristensen et al., 2017). Risk and protective factors, along with additional covariates identified across the studies are summarized in (Figure 2).

3.4 | Significant outcomes

As the studies highlighted a number of factors, results are presented subdivided across the categories of factors identified, to aid in delineating any patterns or trends. Full details of outcomes, significant associations, and identified covariates are described in Table 2.

TABLE 2 Summary of results

Authors, year	Impacting factors identified	Summary of results	Significant covariates identified
Infant demographic factors			
Tronick & Cohn, 1989	Infant gender Infant age	Mother–son dyads spent more time in synchrony than mother–daughter dyads at 6 and 9 months $F(1, 48) = 3.24, p < .05$ No age-related change in association with synchrony	n/a
Weinberg et al., 1999	Infant gender	Mother–son dyads had higher synchrony scores than mother–daughter dyads during the first play session of FFSF $t(1, 74) = 2.04, p < .05$ Mother–daughter dyads took less time in repairing nonsynchronous interactions than mother–son dyads $t(1, 74) = -1.34, p < .02$	n/a
Physiological factors—premature birth			
Feldman, 2006	Premature birth Infant physiological measures Infant sleep	Synchrony shown to be more prevalent in full-term infants compared with premature groups $X^2(1, N = 71) = 4.70, p < .05$ Synchrony shown to be more prevalent in infants with high vagal tone $X^2(1, N = 71) = 8.89, p < .01$ Synchrony shown to be more prevalent in infants with organized sleep–wake cycles $X^2(1, N = 71) = 4.12, p < .05$ Sleep–wake cycles, vagal tone, orientation, and arousal modulation at term age were all uniquely predictive of mother–infant synchrony at 3 months	n/a
Feldman & Eidelman, 2007	Premature birth Maternal behavior Maternal depression Infant vagal tone	Vagal tone predicted synchrony in preterm dyads $\beta = .33, p < .05$ Vagal tone predicted synchrony in full-term dyads $\beta = .27, p < .05$ Maternal postpartum behavior predicted synchrony in preterm dyads $\beta = .27, p < .05$ Maternal postpartum behavior predicted synchrony in full-term dyads $\beta = .28, p < .05$ Maternal depressive symptoms predicted synchrony in preterm dyads $\beta = -.29, p < .05$ Home environment predicted synchrony in preterm dyads $\beta = .27, p < .05$	n/a
Lester et al., 1985	Premature birth	Number of dyads with coherence peaks at 3 months significantly greater for term infants than preterm $X^2, df = 1, p < .05$ Number of dyads with coherence peaks at 5 months significantly greater for term infants than preterm $X^2, df = 1, p < .05$	Significant main effect for maternal age $F(3,35) = 7.21, p < .001$
Montirosso et al., 2010	Premature birth	No significant associations between preterm/full-term birth and synchrony	n/a

(Continues)

TABLE 2 (Continued)

Authors, year	Impacting factors identified	Summary of results	Significant covariates identified
Physiological factors--infant physiological factors			
De Graag et al., 2012	Infant sleep	Significant association between higher bouts of infant sleep and "trapping time" (flexibility in synchrony) $\beta = -.33, p = < .01$	Maternal age and synchrony $\beta = -.21, p = < .05$ Feeding type (6 weeks → 5 months) and synchrony Breast → mixed $\beta = -.53, p = < .01$ Breast/mixed → bottle $\beta = -.37, p = < .01$ Breast → breast $\beta = -.29, p = < .05$
Moore & Calkins, 2004	Infant vagal regulation	Dyadic synchrony in normal play was related to Δ HP in the normal play episode. In less synchronous dyads, infants showed greater decreases in HP $r = -.26, p = < .05$ Dyadic synchrony in normal play was related to level of matched affect in normal play $r = .28, p = < .05$ Dyads in the suppressor group were more synchronous than dyads in the nonsuppressor group in normal play ($M = .16$ and $.06$, respectively) $F(1, 58) = 7.05, p = < .05$	Maternal depression predicted lower synchrony in the normal play episode $F(1, 71) = 6.22, p = < .05$
Penman et al., 1983	Neonatal physiological measures (BNBAS)	Mother habituation correlates positively with frequency of cycles of synchrony $r = .62, p = < .05$ Significant association between frequency of cycles of synchrony at 3 months and infant Interactive Ability at birth $r = .67, p = < .05$ No significant association between cycles of synchrony at 3 months and motor maturity, state control, or physiological response at birth	n/a
Physiological factors--maternal biomarkers			
Apter-Levi et al., 2014	Oxytocin (OT) Vasopressin (AVP)	No significant association between levels of OT or AVP and synchrony	n/a
Atzil et al., 2011	Oxytocin (OT)	Significant association between higher OT levels and higher mother–infant synchrony $r = .6107, p = .0204$ In synchronous mothers, significant correlations between OT with left NAcc β values $r = .7673, p = .0014$ In synchronous mothers, significant correlations between OT and right amygdala β values $r = .6490, p = .012$	n/a

(Continues)

TABLE 2 (Continued)

Authors, year	Impacting factors identified	Summary of results	Significant covariates identified
Busuito et al., 2019	SNS PNS (RSA, SC, HP)	Synchrony in reunion episode correlated with mothers' reunion RSA $r(102) = .22, p < .05$ Synchrony in reunion episode correlated with mothers' reunion HP $r(103) = .24, p < .05$ Significant association between mothers with lower HP and less behavioral synchrony $F(1, 100) = 6.14, p = .05, \eta^2 = .10$ Significant association between higher infant RSA and less behavioral synchrony $F(2.72, 204.04) = 6.34, p < .01, \eta^2 = .08$ Significant association between lower maternal RSA and less behavioral synchrony $F(1, 94) = 3.98, p < .05, \eta^2 = .04$ No significant association between mother and infant SNS arousal and synchrony	Infant age positively correlated with infant HP $F(1, 85) = 6.06, p < .05, \eta^2 = .07$ Maternal education positively correlated with mothers' HP $F(1100) = 11.07, p < .01, \eta^2 = .10$ Maternal age inversely related to mothers RSA $F(1, 94) = 3.98, p < .05, \eta^2 = .04$
Gordon et al., 2017	Testosterone (T) Oxytocin (OT)	Significant association between OT levels and synchrony at t_2 $R^2 = .225, F(3, 31) = 2.99, p < .05$ No significant association between T levels and synchrony No significant association between the interaction of OT and T and synchrony	n/a
Maternal mental health factors			
Coburn et al., 2015	Depression Daily life hassles Stress	Significant association between prenatal depressive symptoms and shorter durations in non-negative engaged states $\beta = -.29, p \leq .01$ Significant association between prenatal depressive symptoms and longer durations in negative engaged states $\beta = .35, p \leq .001$ Significant association between prenatal perceived stress and shorter duration in negative engaged states $\beta = -.21, p < .05$ No association between prenatal daily life hassles and any dyadic behavior	n/a
Field et al., 1989	Maternal depression	Nondepressed dyads spent more time in synchrony than depressed dyads $t(10) = 2.23, p < .05$	n/a
Field et al., 1990	Maternal depression	Synchrony higher in nondepressed dyads but no significant association	n/a
Granat et al., 2017	Maternal depression Maternal anxiety	Gaze synchrony durations were lowest for depressed mothers $F(2, 92) = 3.62, p < .05, \eta^2 = .07$ Gaze synchrony durations highest for anxious mothers $F(2, 92) = 3.62, p < .05, \eta^2 = .07$ Touch synchrony more frequent in anxious mothers $F(2, 92) = 4.64, p < .05, \eta^2 = .09$	n/a

(Continues)

TABLE 2 (Continued)

Authors, year	Impacting factors identified	Summary of results	Significant covariates identified
Kaitz et al., 2010	Maternal anxiety disorders	No significant associations	n/a
Lotzin et al., 2015; 2016	Maternal mood disorder Maternal emotion regulation	Maternal depressive symptoms significantly positively related to gaze synchrony $\beta = .32, 95\% \text{ CI } [.12, .51], p = .002$ Maternal emotion dysregulation significantly related to gaze synchrony $\beta = .40, 95\% \text{ CI } [.20, .59], p = .001$ Maternal emotion dysregulation significantly related to facial affect synchrony $\beta = .34, 95\% \text{ CI } [.16, .51], p = .001$	n/a
Moore et al., 2016	Maternal anxiety during pregnancy	Mothers' prepartum verbal positivity significant predictor of synchrony $\beta = -.26, p < .05$ Mothers' prepartum anxiety significant predictor of synchrony $\beta = -.40, p < .01$	Mothers' positive affect during FFSF meant prepartum verbal positivity no longer a significant predictor, but maternal positive affect a significant predictor $\beta = -.25, p < .05$
Tarullo et al., 2017	Maternal chronic stress	Positive engagement synchrony significantly associated with lower maternal hair cortisol (HCC) $r(112) = -.27, p < .04$ Positive engagement synchrony significantly associated with lower infant average salivary cortisol (SCC) $r(77) = -.29, p < .01$ Positive engagement synchrony significantly associated with lower infant waking SCC $r(77) = -.25, p < .05$	Higher maternal HCC associated with lower SES $r(119) = -.25, p = .007$
Weinberg et al., 2008	Maternal depression Maternal panic disorder	No significant association of differences in interactive behavior by diagnostic group	n/a
Weinberg et al., 2006	Maternal depression	No main effect for synchrony Significant "group x gender" association where mother-son dyads in low symptom group had higher synchrony than mother-daughter dyads $F[\text{df} = 2, 126] = 3.23, p < .05, w^2 = .03$	n/a
Miscellaneous factors			
Gratier, 2003	Immigrant experience	Immigrant dyads showed less interactional synchrony than the nonimmigrant groups $t(58) = 2.7, p < .01$ Within-group variability was greater for immigrants than non-immigrants	Social support was lower for immigrant mothers $X^2(4) = 16.1, p < .005$ Edinburgh Postnatal Depression Scale scores higher in immigrant mothers $t(58) = 3.37, p < .005$
Kristensen et al., 2017	Intervention for maternal depression	Levels of dyadic synchrony in intervention group had significantly improved at follow up $p < .001$	n/a

(Continues)

TABLE 2 (Continued)

Authors, year	Impacting factors identified	Summary of results	Significant covariates identified
Markova et al., 2020	Maternal playful singing	<p>Significant association between playful singing duration and gaze synchrony $z = 2.03, p < .04$</p> <p>Significant association between playful singing duration and affect synchrony $z = 4.69, p < .001$</p> <p>Significant association between length of rhyming games and higher gaze synchrony $z = 3.88, p < .001$</p> <p>Significant association between length of rhyming games and lower affect synchrony $z = -2.86, p < .004$</p>	n/a
Tuladhar et al., 2018	Mothers' perception of how they were parented	<p>Women who perceived their fathers as overprotective had higher engagement synchrony than those who perceived their fathers as low on overprotection $t(49.8) = -2.21, p < .03, d = -.55$</p>	n/a

3.5 | Infant demographic factors

A significant association was reported between infant gender and dyadic synchrony in two studies. Tronick and Cohn (1989) and Weinberg et al. (1999) both reported that

mother–son dyads spent more time in synchrony than mother–daughter dyads during the first play episode of the FFSF paradigm. Additionally, Weinberg et al. (1999) reported that after an interruption in dyadic synchrony, mother–daughter dyads took less time in repairing the

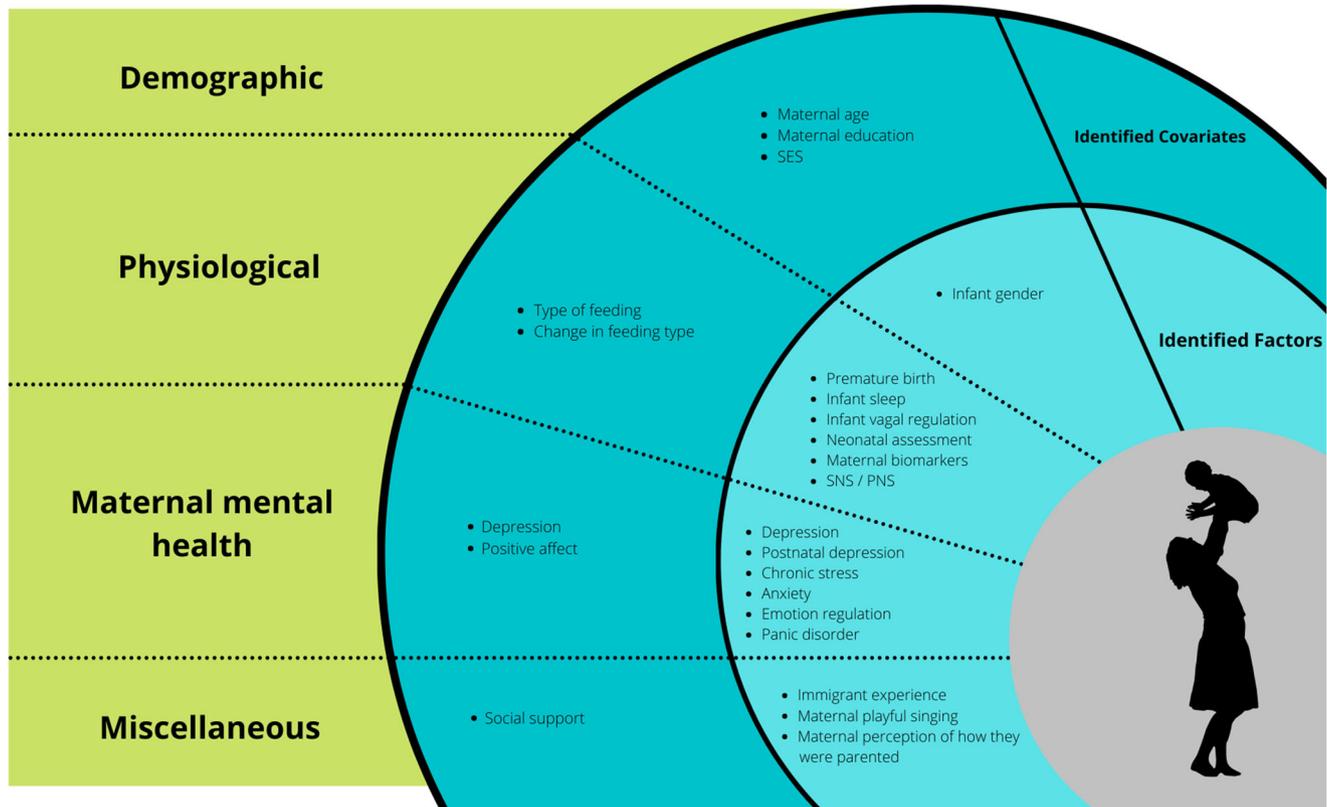


FIGURE 2 Summary of identified factors and covariates by subgroup

disruption than mother–son dyads. No significant associations were reported between the age of the infant and dyadic synchrony scores.

3.6 | Physiological factors: Premature birth

Significant associations were reported between dyadic synchrony and premature birth, with implications that synchrony scores are higher in dyads with a full-term infant compared to those dyads with a preterm infant (Feldman, 2006; Lester et al., 1985). Comparing vagal regulation in full- and preterm dyads suggested that higher synchrony was more prevalent in infants with a high vagal tone (Feldman, 2006), and that vagal tone was predictive of synchrony in both full- and preterm dyads (Feldman & Eidelman, 2007). Maternal postpartum behavior was predictive of synchrony in both full- and preterm dyads, and maternal depressive symptoms were negatively associated with synchrony in preterm dyads (Feldman & Eidelman, 2007). A significant association was also reported between higher scores on the Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1978) Scale and dyadic synchrony in preterm dyads (Feldman & Eidelman, 2007). However, Montirosso et al. (2010) found no significant associations between full- or preterm birth and levels of dyadic synchrony.

3.7 | Physiological factors: Infant physiological factors

Of the studies that observed infant physiology, one study found a significant association between an increase in sleep bout duration (defined in this study as a period of sleep in which the child does not stir) between 6 weeks and 5 months of age and lower “Trapping Time” scores, denoting the flexibility of synchronous gaze between mother and infant (de Graag et al., 2012). This study identified confounding variables in maternal age, with older mothers and type of feeding between 6 weeks and 5 months of age associated with lower “Trapping Time.” Feldman (2006) also reported significant associations between infants with organized sleep–wake cycles and dyadic synchrony.

When observing infant vagal regulation, a significant negative association was found between infant heart period (HP) and dyadic synchrony (Moore & Calkins, 2004). Mother–infant dyads who showed a decrease in respiratory sinus arrhythmia (RSA) between normal play and still face episodes in the FFSF paradigm (suppressor group) were more synchronous than dyads in the nonsuppressor group. Maternal depression was identified as a covariate,

predicting lower synchrony between the dyad during the normal play episode of the FFSF paradigm.

In a study linking dyadic synchrony to scores on the Brazelton Neonatal Behavioral Assessment Scale (BNBAS), a significant positive association was found between dyadic synchrony at 3 months and infant Interactive Ability at birth (Penman et al., 1983). No associations were found between synchrony and any other dimensions of the BNBAS (motor maturity, state control, or physiological response).

3.8 | Physiological factors: Maternal biomarkers

Of the three studies observing oxytocin, two studies (Atzil et al., 2011; Gordon et al., 2017) found a significant association between higher levels of maternal oxytocin and higher mother–infant synchrony scores. A third study (Apter-Levi et al., 2014) found no significant associations between the mothers’ hormone levels and dyadic synchrony. No significant associations were reported between either levels of vasopressin (Apter-Levi et al., 2014) or testosterone (Gordon et al., 2017) and dyadic synchrony.

A number of associations were found between mother and infant PNS reactions and dyadic synchrony (Busuito et al., 2019). In the reunion episode of the FFSF paradigm, synchrony was positively associated with mothers’ RSA and HP. Across all episodes of the FFSF paradigm, there was a significant association between mothers with lower HP and less behavioral dyadic synchrony. Higher infant RSA was associated with less behavioral synchrony but conversely, higher maternal RSA was associated with higher synchrony scores. The same study reported that there were no significant associations between SNS reactions, such as skin conductance, and dyadic synchrony.

3.9 | Maternal mental health

In two studies, significant negative associations were found between prenatal depressive symptoms and dyadic synchrony (Coburn et al., 2015; Field et al., 1989). Conversely, Lotzin et al. (2015) reported a significant positive association between maternal prenatal depressive symptoms and gaze synchrony. Additionally, two studies reported no significant associations between prenatal depression and synchrony (Field et al., 1990; Weinberg et al., 2008); however, Field et al. (1990) did report a trend towards synchrony scores being higher in nondepressed dyads. Further, Lotzin et al. (2015) reported that emotion dysregulation mediated the relation between maternal depressive symptoms and gaze synchrony; as well as

reporting significant positive associations between emotion dysregulation and synchrony, relating to both gaze synchrony and facial affect synchrony.

With regards to postnatal depression, Granat et al. (2017) report a significant association between shorter durations of gaze synchrony in depressed mothers. Weinberg et al. (2006) also observed maternal postnatal depression although they did not report any main effect for synchrony. However, this study did report a significant “group \times gender” association whereby mother–son dyads in the low depressive symptoms group had higher synchrony scores than mother–daughter dyads in the same group.

A significant negative association was reported between maternal anxiety during pregnancy and synchrony (Moore et al., 2016). Interestingly, a significant positive association was reported between generalized anxiety and synchrony, in the forms of touch and gaze synchrony (Granat et al., 2017). One further study reported no significant associations between maternal anxiety disorders and dyadic synchrony (Kaitz et al., 2010)

Significant associations were also reported between lower levels of maternal stress and higher synchrony scores (Coburn et al., 2015; Tarullo et al., 2017). When measuring parental daily life hassles, however, no significant associations were found (Coburn et al., 2015).

3.10 | Miscellaneous factors

Four studies included in the review reported associations that did not fit neatly into an overall category. The first study observed the experience of Indian immigrant mothers living in the United States compared to nonimmigrant mothers living in India, the United States, and France (Gratier, 2003), and reported immigrant mothers showing significantly less interactional synchrony with their infants than nonimmigrants. Identified covariates suggested that social support was lower for immigrant mothers, and that depressive symptoms were higher in immigrant mothers.

A second study looking at the use of playful singing in mother–infant face-to-face interactions (Markova et al., 2020) found a significant positive association between playful singing duration and gaze synchrony as well as affect synchrony. The study also reported a significant association between the length of rhyming games played in face-to-face interaction and gaze synchrony as well as affect synchrony.

A further study (Tuladhar et al., 2018) asked mothers about their perceptions of how they themselves were parented, using the Parental Bonding Instrument (PBI; Parker et al., 1979). A significant association was reported between mothers who perceived their own fathers as overprotec-

tive and dyadic engagement synchrony scores between the mother and her own infant.

The final study included the development and implementation of an intervention aimed at first-time mothers to reduce depressive symptoms, and increase self-confidence and dyadic synchrony between mother and infant (Kristensen et al., 2017). This study reported a significant association between members of the intervention group and improved synchrony at the intervention follow up.

3.11 | Critical evaluation and risk of bias

Final scores for the included studies ranged from 22 to 42. The most notable issue identified across the studies was the reporting of sample size. Only one study (Lotzin et al., 2015) reported sample size calculations, with the majority of papers acknowledging insufficient power within the study. A second issue noted across the study corpus was the recruitment method, with many studies using participants who were already enrolled in another study previously. Additionally, inclusion and exclusion criteria were not explicitly reported in several studies. A final issue for consideration is that in many papers, the infants' age was reported as a singular number (e.g., 3 months), not necessarily representative of range or mean. The majority of papers, however, did use standardized measures of both the identified factor and dyadic synchrony. Both validity and reliability of the measures were also often reported. All papers were rated highly for clarity in describing the procedure and data analysis, as well as the papers' findings. It is also notable that the studies scoring the lowest ratings were published in the early 1980 s.

4 | DISCUSSION

This systematic review sought to identify and synthesize predictive factors that have been shown to impact behavioral synchrony within the mother–infant dyad. We relied on study data to identify study characteristics, and procedures and coding schemes that were employed in measuring dyadic behavioral synchrony. To our knowledge, it is the first review of this behavioral construct in infants aged 3–9 months. The key findings of the review can be broken down into four main categories: demographic factors, where there is evidence that infant gender is associated with dyadic synchrony between mother and infant; physiological factors, where there is little evidence of consistent associations between hormonal biomarkers and synchrony, however, clear patterns emerge between gestational age at birth and mother–infant synchrony, as

well as PNS responses, in both mother and infant, and synchrony; maternal mental health factors, where some, albeit inconsistent associations are reported for pre- and postnatal depression as well as anxiety and stress; and miscellaneous factors, which suggest that maternal playful singing as well as the life experiences of the mother, including access to social support, associate with levels of dyadic synchrony. These results would suggest a strong argument towards social determinants of health playing a large part in the synchronous interactions between mother and infant, which are potentially underpinned by a number of biological factors particular to each dyad (Feldman, 2007; Reyna & Pickler, 2009).

4.1 | Implications for research

The findings from this review have implications for a number of avenues of future research. As a foremost limitation of the extant literature is underpowered, small studies, it would be useful to undertake studies with a larger sample size to ensure greater effect sizes when reporting associations. While it should be acknowledged that studies analyzing mother–infant interactions are typically small (Montirosso et al., 2010), there may be scope to increase the sample size to higher numbers than were reported in the majority of the included papers. Additionally, it could be advisable for cohorts to work together to pool datasets or create meta-analyses, where measures are standardized and held constant.

As a lack of diversity is a further limitation of the studies thus far, potential research could aim to understand the impact of families in higher-risk environments, as well as families living in conditions of multiple deprivation. As there is a lack of studies from LMICs, this could be a further route to understanding mother–infant interactions across diverse cultures (Gajaria & Ravindran, 2018; Parsons et al., 2011), and recruiting participants from different ethnic backgrounds would also be advisable.

A further avenue for potential research stems from the various covariates identified within the studies. Across the papers, a number of social and structural determinants were identified as covariates (e.g., social support, maternal age, maternal education). While there is the implication that these variables are important in the development of dyadic behavioral synchrony, they are yet to be explored fully in studies of this age group. Interestingly, in older age groups, these factors have been identified and studied more fully, for example, maternal age and synchrony in toddlerhood (Hammer et al., 2019), and socioeconomic risk factors and synchrony in toddlerhood (Skuban et al., 2006). There is potential for these studies to be carried out in

younger infants, with implications for supporting mothers and families from the perinatal stage.

Similarly, there appears to be a tendency for authors to concentrate on a small amount of maternal mental health factors, specifically, depression diagnosed before pregnancy, postnatal depression, anxiety, and stress. In limiting the work to such a small amount of disorders, and particularly concentrating on depressive symptoms, there is an obvious lack of studies focused on additional clinical diagnoses. While there were mixed results regarding maternal mental health, there is certainly a potential to claim that there is an association between mental health and mother–infant synchrony. There is, therefore, an implication that further studies regarding other mental health disorders, such as schizophrenia or bipolar disorder could yield interesting results (Davidsen et al., 2015; Harder et al., 2015).

Furthermore, in regards to maternal mental health, the results from the review have garnered mixed results and different associations depending on the mental health diagnosis. There is an implication that not all mental health disorders lead to a lack of synchrony, for example, mothers with anxiety were shown to have higher scores for touch and gaze synchrony, which in turn could lead to overstimulation for the infant and fewer chances to develop a sense of self or agency. The results imply that there is an optimal range for synchrony with the potential for dyads to be hyper- or hypo-synchronous. Studies into further mental health disorders could be useful in understanding where dyads sit on this spectrum of synchrony, providing further support for mothers who need it.

As an alternative route of research, there is also scope to understand the ways in which positive mental health factors are related to mother–infant synchronous behavior. The results within this review have also suggested that protective factors, such as perceived social support and access to educational interventions can improve synchrony scores, with an implication that this is mediated through improved maternal mental health (Gratier, 2003). While this implication is evident, further research into this area would certainly be beneficial. Additionally, research into other protective factors within maternal mental health, for example, coping skills and resilience may also prove fruitful in finding links between maternal mental health and mother–infant synchrony (McKelvey et al., 2002; Davis et al., 2003). This is in line with broader movements within public health aiming to place an emphasis on parent–infant mental health as a driving force for social development (Davidsen et al., 2015).

A further consideration is the indirect impact of external risk and protective factors to family life, for example, what impact shared and personal technology may have on proximal relationships and interactions (Myruski et al.,

2018). Additional areas of study may consider the effects of the relationship between parents, including physical and financial support from the father as well as intimate personal violence within the home (Brunelli et al., 1995; Letourneau et al., 2013).

Finally, this systematic review considers only the relationship between the mother and her infant. While the primary caregiver of a young infant has traditionally been considered to be the mother, this is perhaps reflective of historical attachment literature based on Western family structures. Certainly, there are many other family members who interact with the child on a daily basis, for example, it has been argued that the caregiving role of fathers has evolved in many societies and cultures and that fathers' involvement (Ahnert & Schoppe-Sullivan, 2020) and the implications of fathers' mental health (Sweeney & MacBeth, 2016) should be looked at in more detail. There is also scope to look at other caregivers within the household, including partners in LGBTQI+ relationships (Feugé et al., 2020; McInerney et al., 2021) as well as extended family members including grandparents, siblings, and further kinship carers in both high- and low- and middle-income (LMIC) countries (Arnold et al., 2011; Gajaria & Ravindran, 2018; Liang et al., 2021).

4.2 | Methodological considerations

When considering the heterogeneity of the current findings, methodological decisions made in carrying out the review should be taken into account. To maximize conceptual clarity of the construct, the inclusion and exclusion criteria for this review included all studies that identified behavioral dyadic synchrony as the reported outcome, potentially increasing the breadth of influencing factors that could be included. However, conversely, the criteria also excluded any form of dyadic interaction that was not specifically identified as synchrony. There was, therefore, also the potential to exclude studies that were measuring a form of dyadic synchrony without having identified it as such, for example, a number of papers were excluded for identifying the dyadic process as an "interaction," however, the definition of said interaction may have aligned very closely with the operationalization of dyadic synchrony. Additionally, as mentioned earlier, there is a deficit of clarity surrounding how the constructs relating to dyadic interactive processes are similar or different, and where these similarities and differences begin and end (for a similar methodological discussion regarding the measurement of synchrony see Leclère et al., 2014). As discussed, synchrony is a well-defined concept, with well-validated measures. However, in making decisions around inclusion and exclusion of certain conceptual terms, it should be highlighted that there are implications in how

this may have influenced the review overall. In choosing to include only studies which look specifically at synchrony, we accept that only a limited amount of measures and paradigms would be included in the review, and as such, the theoretical underpinnings of particular schools of thought will occur more often in the literature. Further reviews could, therefore, be carried out with these considerations in mind.

A further consideration is the inclusion of all studies regardless of an observational procedure. A number of the studies utilized the FFSF paradigm—an experimental paradigm that aims to manipulate the behavior and affect of the dyad. Other studies used an observational paradigm, coding a face-to-face interaction with no manipulation. It could be suggested that the differences in observation lead to differences in behavioral coding with implications for the data. Additionally, a number of different forms of synchrony have been included as measured across the studies, including gaze synchrony, behavioral synchrony, and interactional (vocal) synchrony. While all falling under the operationalization of synchrony, there is potential for these different behaviors to return different results.

Where some studies reported mixed results concerning particular factors, for example, physiological factors such as premature birth, this could also be a methodological consideration. The differences in these results could potentially stem from the fact that the infants in Montirosso et al.'s study were slightly older (age 6–9 months) compared to the infants in the other studies (age 3–5 months). The Montirosso et al. study also had a smaller sample size than both Feldman (2006) and Feldman and Eidelman (2007); however, the Lester et al. (1985) study reported the smallest sample size of these studies. Additionally, while Feldman (2006), Feldman and Eidelman (2007), and Lester et al. (1985) used a low-stress face-to-face interaction procedure, Montirosso et al. (2010) used a FFSF procedure, which is designed to elicit a stress response in the infant.

Due to the wide breadth of the literature search, many of the factors identified as associating with synchrony within this review are only measured in a small amount of papers, with a number of factors only identified in a single study. Given the heterogeneity of the factors identified as associating with dyadic behavioral synchrony in this review, it is not possible at this time to conduct a meta-analysis of the data. However, if a review was to encompass more of the dyadic processes into one data set, this may be a viable option.

4.3 | Limitations

A number of limitations pertaining to the studies within the review may also account for the heterogeneity of findings. As previously discussed, the critical evaluation

undertaken on the included studies produced a wide range of scores, with final scores ranging from 22 to 42, indicating that the level of quality and risk of bias varied widely across papers. Notably, small sample sizes across nearly all of the studies create underpowered work, from which it becomes difficult to conclude meaningful associations. Recruitment methods were often less than ideal with many authors using a cohort recruited from a larger study within their lab, leading to convenience sampling that may not be generalizable to a wider population. As the papers span four decades, it should be noted that papers scoring the lowest ratings on quality were published in the 1980s, with more recent papers showing higher scores, and therefore, demonstrating higher levels of methodological quality.

An additional limitation of a number of the studies, which was not highlighted in the critical evaluation, concerns the reporting parameters of effect sizes. It should be noted that a number of papers only reported p values as $< .05$ or $< .01$, with no reporting of the exact value. This makes it difficult to compare results as there is missing detail regarding effect sizes of associations reported (Halsey, 2019).

Within the studies, there is also a lack of diversity regarding SES and ethnicity, with the majority of studies recruiting low-risk, middle-class, well-educated families. The majority of participants across all studies were also identified as White. A small number of studies targeted participants in contexts of risk (Coburn et al., 2015; Field et al., 1989; 1990), in which case the participants were identified as Black or Hispanic families of low SES, further lending support to the theory that social determinants of health, including SES, ethnicity, and maternal mental health, are anticipated risk factors for decreased synchrony in the mother–infant dyad.

5 | CONCLUSION

The evidence in this review suggests that a large number of heterogeneous factors have an influence over the levels of synchrony experienced in the mother–infant dyad. Social factors such as mental health, social support, and social interventions are implicated, as well as a number of biological factors, such as premature birth, infant physiological factors, and maternal genetic biomarkers. The potential for such social determinants of health to interact increases the risk that some dyads may face in developing a strong interactive relationship. Overall, there are still a number of areas where additional research could be undertaken. Synchrony is a well-established construct with a defined operationalization and valid and reliable psychometric tools, and it is, therefore, certainly possi-

ble to identify further areas of risk for mothers and their infants, and to inform population-level programs, designed to offer support and education to create an optimal environment for early interaction and formative attachment relationships within the sphere of public health (Jeong et al., 2021).

CONFLICT OF INTEREST

AM is a member of the steering group for the NHS Scotland Managed Care Network for Perinatal Mental Health and an adviser to the NHS Education Scotland Perinatal Mental Health Psychological Therapies Matrix. He has held funding from the MRC and the Chief Scientist's Office of the Scottish Government.

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