Received: 4 August 2022 | Revised: 12 February 2023 | Accepted: 15 February 2023
DOI: 10.1002/icd.2414

REVIEW ARTICLE

WILEY

# Measures of infant self-regulation during the first year of life: A systematic review

Tiago Miguel Pinto[1,2] | Bárbara Figueiredo[1]

[1]School of Psychology, University of Minho, Braga, Portugal

[2]Lusófona University/HEI-Lab: Digital Human-Environment Interaction Lab, Porto, Portugal

**Correspondence**
Tiago Miguel Pinto, Universidade do Minho, Escola de Psicologia, Campus de Gualtar, Braga 4700-057, Portugal
Email: tmpinto@psi.uminho.pt

**Funding information**
Portuguese Foundation for Science and Technology; Portuguese Ministry of Education and Science; European Regional Development Fund, Grant/Award Number: POCI-01-0145-FEDER-007653; Fundação para a Ciência e a Tecnologia, Grant/Award Numbers: SFRH/BD/115048/2016, PTDC/SAU/SAP/116738/2010; Foundation for Science and Technology, Grant/Award Number: UIDB/05380/2020

## Abstract

This study aimed to systematically review the measures used to assess infant self-regulation during the first 12 months of life. This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement protocol. From 235 selected papers, 79 provided information on behavioural and physiological measures to assess infant self-regulation during the first 12 months of life. Thirty-six behavioural (30 observational and 6 parent-report) and five physiological different measures were identified. Studies with a longitudinal design, comprising larger samples, and aiming to assess infant self-regulation later in infancy, mostly used behavioural measures than physiological measures. Studies comprising lower samples and aiming to assess infant self-regulation earlier in infancy, mostly used observational than parent-reported measures. Studies targeting younger infants used physiological measures and studies targeting older infants used behavioural measures, with observational measures used with younger infants and parental-reported measures used with older infants during the first year of life. When measuring self-regulation is important to consider infant's age, to fit the measurement procedures with the self-regulation development level.

**KEYWORDS**
behavioural measures, infant, observational measures, parent-reported measures, physiological measures, self-regulation

## 1 | INTRODUCTION

Self-regulation results from the activity of "processes that serve to modulate reactivity" (Rothbart et al., 2011, p. 442) and grants adequate behaviours and appropriate responses to situational demands (van den Bergh & Mennes, 2006). Self-regulating processes vary according to the infant's age and reactivity pattern and include orienting, fearful inhibition, angry attack, surgent or extraverted approach, and behaviour control the effort based on the executive attention system (Rothbart et al., 2011).

Infants can engage in sensorimotor activities and voluntarily contact others, and this ability plays a major role in the development of self-control throughout the life cycle (Crockenberg & Leerkes, 2004; Morales et al., 2005; Rothbart et al., 2011). Empirical evidence indicated that several self-regulation processes manifested early in infancy occur at a nonconscious and automatic level (e.g., Aarts, 2007; Bargh & Morsella, 2008). Behaviours manifested during the first 12 months of age, namely self-soothing and orienting, serve self-regulatory functions (Rothbart et al., 1992, 2011). Orienting is an effective way of lowering the expression of negative affect, serving as a major self-regulatory mechanism (e.g., Sheese et al., 2009). Infants who can quickly disengage from distressing objects are less susceptible to negative affect and easier to soothe (Crockenberg & Leerkes, 2004; Morales et al., 2005).

Self-regulation is a major developmental task in infancy. Physiological and behavioural states are progressively regulated during the first year of life (Bell & Deater-Deckard, 2007; Calkins, 2009). Infants start first to regulate their physiological states which promotes their emotional, cognitive and behavioural regulation (Calkins, 2009; Porges, 2007). Vagal inhibition in response to stress and activation during recovery from stress are both associated with effective self-regulatory behaviours, such as higher soothability (e.g., Bazhenova et al., 2001; Ham & Tronick, 2006; Stifter & Corey, 2001), while difficulties in regulating vagal tone during stressing tasks are associated with self-regulatory difficulties in later ages (e.g., El-Sheikh et al., 2009; Graziano & Derefinko, 2013). Infant self-regulation is a resource to promote further development, while self-regulation difficulties predict several adjustment problems, including internalizing and externalizing problems, lower social skills, and disrupted physiological regulation to stress (e.g., Eisenberg et al., 2004; Perry et al., 2016; Williams et al., 2016).

Infant self-regulation has been distinctly conceptualized, operationalized, and measured in the literature, leading to several struggles, namely, to compare results from different studies (Bell & Deater-Deckard, 2007; Bridges et al., 2004; Cole et al., 2004; Nigg, 2017). Namely, infant self-regulation has been conceptualized and operationalized using different indicators—physiological (e.g., vagal reactivity), behavioural (e.g., orienting regulation, self-soothing, inhibition), and cognitive and emotional (e.g., effortful control). Likewise, different measures have been used to assess this construct, namely observational or parent-reported measures (Bell & Deater-Deckard, 2007; Cole et al., 2004).

Assessing self-regulation early in infancy is a major issue to understand self-regulatory processes in typically developing infants and identify infants with self-regulation difficulties. A systematic review of the measures used to assess infant self-regulation can add to the literature in this field by providing evidence on the measures more adequate to assess physiological, emotional, cognitive, or behavioural regulation. This may contribute to assisting researchers and clinical practitioners to make empirically based decisions and select the most adequate measures to assess infant self-regulation at different ages and in diverse contexts and circumstances. This study aimed to systematically review the measures used to assess infant self-regulation during the first 12 months of life.

## 2 | METHOD

This systematic review was conducted according with the standard protocol based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher et al., 2009).

### 2.1 | Literature search

The literature search for relevant papers was conducted on September 27, 2022 in three databases: MEDLINE, ISI Web of Knowledge, and PsycINFO. This search was conducted to identify manuscripts that referred to infant self-regulation during the first 12 months of life. The search was limited to English, Portuguese, Spanish, and French written articles, and articles conducted with human samples. The following search term was used: infant (title/abstract) AND self-regulation (title/abstract). The electronic search was first performed by one author (TMP) and then independently replicated by another author (BF). In the first stage, the titles, and the abstracts were independently analysed by two authors (TMP and BF) to identify potentially relevant manuscripts. In the second stage, the full texts of the potentially relevant articles were independently evaluated by the two authors for inclusion and exclusion criteria examination. In case of disagreement, the consensus was reached through discussion.

### 2.2 | Inclusion and exclusion criteria

Studies were included according to the following criteria: (a) original studies; (b) studies including infants aged between 0 and 12 months; (c) and studies assessing physiological, emotional, cognitive, or behavioural regulation. Exclusion criteria included: (a) non-original research (e.g., literature reviews, systematic reviews, or meta-analysis); (b) research projects; (c) studies with a qualitative design; and (d) studies assessing self-regulation in infants above 12 months of age.

### 2.3 | Quality assessment

The quality of all studies was assessed according to a Quality Index (QI) checklist based on the system of Downs and Black (1998). This QI is a 27-item checklist that was designed to assess the methodological quality of randomized and non-randomized studies and is comprised of five subscales. As some items did not apply to most of the revised studies, 14 from the total 27 items were selected to score the studies. Some examples of the items used are as follows: (1) “Are the main outcomes to be measured clearly described in the Introduction or Methods section?”, (2) “Were the statistical tests used to assess the main outcomes appropriate?”, and (3) “Were the main outcome measures used accurate (valid and reliable)?” All items are scored between zero and one, with exception of one item that was scored between 0 and 2. Total scores range between 0 and 15, with higher scores indicating better methodological quality. Papers scoring more than 10 were qualified as good, those scoring between seven and 10 were qualified as moderate, and those scoring less than seven were qualified as poor.

### 2.4 | Data extraction

Data from studies that met the inclusion criteria were extracted for three data sheets (see Tables 1–3). This information was extracted by one author (TMP) and then reviewed by another author (BF). The studies were organized according to the objective of this systematic review.

# 3 | RESULTS

## 3.1 | Databases search

The literature search identified 235 relevant papers (after the elimination of duplicates). After the examination of titles and abstracts, 60 non-relevant papers were excluded. The full texts of the remaining 175 papers were examined for inclusion/exclusion criteria. After the full-text reading, 96 papers were excluded as they met one or more exclusion criteria, and 79 papers were included in the review (see Figure 1).

## 3.2 | Articles reviewed

Most studies (77.2%) were conducted in the United States (*n* = 38), or European countries (*n* = 23), and one study was conducted both in the United States and Austria (Coyle et al., 2012). More than half of the studies presented a longitudinal design (69.6%; *n* = 55) and assessed infant self-regulation one time across the 12 months of life (93.7%; *n* = 7). Studies' sample size ranged between 15 and 7450 infants (Grenier et al., 2003; Radesky et al., 2014). Infant's ages ranged between 0 and 12 months (Anzman-Frasca et al., 2013; Bates et al., 2021; Cevasco-Trotter et al., 2019; Freedman et al., 2019; Sun et al., 2022; Twohig et al., 2021). A high percentage of studies were qualified as good (78.5%; *n* = 62) and the remaining studies were qualified as moderate (see Tables 1–3).

Regarding the measures to assess infant self-regulation during the first 12 months of life, most studies used only behavioural measures (81%; *n* = 6), 12 studies (15.2%) used only physiological measures, while seven studies used both behavioural and physiological measures (8.9%). From the studies assessing infant self-regulation with behavioural measures, 46 studies (58.2%) used observational measures, 20 (25.3%) studies used parent-reported measures, and one study used both observational and parent-reported measures (Anzman-Frasca et al., 2013). A total of 41 behavioural or physiological measures were identified to assess infant self-regulation during the first 12 months of life. Overall, these measures presented good psychometric characteristics.

## 3.3 | Behavioural measures to assess infant self-regulation during the first year of life

### 3.3.1 | Observational measures

Table 1 summarizes the observational behavioural measures to assess infant self-regulation during the first 12 months of life. More than half of studies using observational measures had a longitudinal design (61.7%; *n* = 29). Studies' sample size ranged between 15 and 1053 infants, $M_{sample} = 183.02$ infants (Grenier et al., 2003; Salisbury et al., 2007). Infant's age ranged between 0.1 and 12 months, $M_{age} = 3.72$ months. A total of 30 different observational measures were identified in the 47 studies, assessing self-regulation at emotional, cognitive, and behavioural levels (see Table 1).

Most studies used one observational measure(89.4%; *n* = 42). Some of the studies that used more than one observational measure assessed self-regulation more than one times in different ages across the first 12 months of life, assessing behavioural regulation in neonates and emotional and cognitive regulation later in infancy (Feldman et al., 2002; Lundqvist-Persson, 2001; Wolf et al., 2002). On the other hand, other studies used different observational measures to assess infant self-regulation at different levels—emotional, attentional, and behavioural (Brandes-Aitken et al., 2019; Hendry et al., 2022; Wiebe et al., 2014).

The Neonatal Intensive Care Unit Network Neurobehavioral Scale (NNS; Lester & Tronick, 2004) and the Face-to-Face Still-Face paradigm (FFSF; Tronick et al., 1978) were the observational measures used by more studies(51.1%; *n* = 24). The NNS was the observational measure used by more studies to assess behavioural

**TABLE 1** Observational measures to assess infant self-regulation during the first 12 months of life.

| Self-regulation measure | First author (year of publication) | Country | Design | *N* | Age (months) | QI |
|---|---|---|---|---|---|---|
| Face-to-Face Still-Face paradigm | Lan et al. (2022) | China | Cross-sectional | 204 | 6.6 | 11 |
| Face-to-Face Still-Face paradigm | Abney et al. (2021) | USA | Cross-sectional | 114 | 5 | 10 |
| Face-to-Face Still-Face paradigm | Erickson et al. (2021) | Mexico | Cross-sectional | 50 | 4.6 | 10 |
| Face-to-Face Still-Face paradigm | Barbosa et al. (2021) | Portugal | Longitudinal | 108 | 3, 9 | 11 |
| Face-to-Face Still-Face paradigm | Beauchamp et al. (2020) | Mexico | Longitudinal | 100 | 6.9 | 11 |
| Face-to-Face Still-Face paradigm | Busuito et al. (2019) | USA | Cross-sectional | 140 | 6 | 12 |
| Face-to-Face Still-Face paradigm | Conradt et al. (2015) | USA | Longitudinal | 128 | 5 | 14 |
| Face-to-Face Still-Face paradigm | Noe et al. (2015) | Germany | Cross-sectional | 68 | 3.9 | 11 |
| Face-to-Face Still-Face paradigm | MacLean et al. (2014) | USA | Cross-sectional | 84 | 4.1 | 10 |
| Face-to-Face Still-Face paradigm | Chow et al. (2010) | USA | Longitudinal | 36 | 6.1 | 8 |
| Face-to-Face Still-Face paradigm | Montirosso et al. (2010) | Italy | Cross-sectional | 50 | 9.2 | 9 |
| Face-to-Face Still-Face paradigm | Crandell et al. (2003) | UK | Cross-sectional | 20 | 2.1 | 8 |
| Face-to-Face Still-Face paradigm | Rosenblum et al. (2002) | USA | Longitudinal | 100 | 7 | 10 |
| Face-to-Face Still-Face paradigm | Weinberg et al. (1999) | USA | Cross-sectional | 81 | 6 | 9 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | McGowan et al. (2020) | USA | Cross-sectional | 661 | 0.1 | 11 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Velez et al. (2018) | USA | Longitudinal | 41 | 1 | 10 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Salisbury et al. (2015) | USA | Longitudinal | 184 | 1 | 12 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Stroud et al. (2016) | USA | Longitudinal | 45 | 1 | 10 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Conradt et al. (2013) | USA | Longitudinal | 482 | 0.3 | 13 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Pineda et al. (2013) | USA | Longitudinal | 75 | 1 | 10 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Coyle et al. (2012) | USA Austria | Longitudinal | 39 | 1 | 12 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Yolton et al. (2011) | USA | Longitudinal | 318 | 1 | 13 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Stroud et al. (2009) | USA | Longitudinal | 318 | 0.5 | 9 |
| Neonatal Intensive Care Unit Network Neurobehavioral Scale | Salisbury et al. (2007) | USA | Longitudinal | 1053 | 1 | 12 |

(Continues)

**TABLE 1** (Continued)

| Self-regulation measure | First author (year of publication) | Country | Design | *N* | Age (months) | QI |
|---|---|---|---|---|---|---|
| Neonatal Behavioral Assessment Scale | Shoaff et al. (2021) | USA | Longitudinal | 370 | 0.5 | 12 |
| Neonatal Behavioral Assessment Scale | Lundqvist-Persson et al. (2012) | Sweden | Longitudinal | 51 | 1 | 9 |
| Neonatal Behavioral Assessment Scale | Hernández-Martínez et al. (2008) | Spain | Longitudinal | 163 | 0.1 | 12 |
| Neonatal Behavioral Assessment Scale | Wolf et al. (2002) | Netherlands | Longitudinal | 30 | 0.3 | 9 |
| Neonatal Behavioral Assessment Scale | Lundqvist-Persson (2001) | Sweden | Longitudinal | 38 | 0.1 | 8 |
| Neonatal Behavioral Assessment Scale | Lester et al. (1996) | USA | Cross-sectional | 44 | 0.1 | 8 |
| Bayley Scales of Infant Development—III | McManus et al. (2020) | USA | Longitudinal | 39 | 3, 6 | 10 |
| Bayley Scales of Infant Development—II | Lundqvist-Persson et al. (2012) | Sweden | Longitudinal | 51 | 3, 6 | 9 |
| Bayley Scales of Infant Development—II | Wolf et al. (2002) | Netherlands | Longitudinal | 30 | 6 | 9 |
| Free play | Egmose et al. (2021) | Sweden | Cross-sectional | 69 | 4 | 11 |
| Free play | Zhang et al. (2014) | China | Cross-sectional | 281 | 6 | 11 |
| Touchscreen approach | Hendry et al. (2022) | UK | Longitudinal | 115 | 10 | 11 |
| Toy prohibition | Hendry et al. (2022) | UK | Longitudinal | 115 | 10 | 11 |
| Touchscreen prohibition | Hendry et al. (2022) | UK | Longitudinal | 115 | 10 | 11 |
| A-not-B task | Hendry et al. (2022) | UK | Longitudinal | 115 | 10 | 11 |
| Early childhood inhibitory touchscreen task | Hendry et al. (2022) | UK | Longitudinal | 115 | 10 | 11 |
| Mother-Infant Face-to-Face Interaction Coding System | Kahya et al. (2022) | Turkey | Cross-sectional | 56 | 4 | 10 |
| Typical daily activity task | Planalp et al. (2021) | USA | Longitudinal | 682 | 4, 8 | 12 |
| Early attention to reading situations | Brandes-Aitken et al. (2019) | USA | Longitudinal | 1204 | 7 | 14 |
| Infant behaviour record | Brandes-Aitken et al. (2019) | USA | Longitudinal | 1204 | 7 | 14 |
| Infant Behavior Rating Scales—Revised | de l'Etoile et al. (2015) | USA | Cross-sectional | 30 | 5.3 | 9 |
| Tronick's Monadic phases | Lin et al. (2014) | USA | Longitudinal | 295 | 3 | 13 |
| Newborn distress pain related behaviour coding | Warnock et al. (2014) | Canada | Longitudinal | 21 | 0.1 | 8 |

TABLE 1 (Continued)

| Self-regulation measure | First author (year of publication) | Country | Design | *N* | Age (months) | QI |
|---|---|---|---|---|---|---|
| Arm Restraint task | Wiebe et al. (2014) | USA | Longitudinal | 218 | 6 | 13 |
| Visual delayed response task | Wiebe et al. (2014) | USA | Longitudinal | 218 | 6 | 13 |
| Novel object habituation task | Wiebe et al. (2014) | USA | Longitudinal | 218 | 6 | 13 |
| Fagan Test of Infant Intelligence | Wiebe et al. (2014) | USA | Longitudinal | 218 | 6 | 13 |
| Toy removal task | Anzman-Frasca et al. (2013) | USA | Longitudinal | 110 | 12 | 13 |
| Manual for the Naturalistic Observation of Newborn Behavior | Ferreira and Bergamasco (2010) | Brazil | Cross-sectional | 32 | 0.5 | 10 |
| Bathing task | Liaw et al. (2010) | Taiwan | Cross-sectional | 24 | 0.5 | 8 |
| Mask presentation task | Sheese et al. (2008) | USA | Cross-sectional | 50 | 6.5 | 11 |
| Caregiving task | Grenier et al., 2003 | USA | Cross-sectional | 15 | 1 | 9 |
| State observation procedure | Feldman et al. (2002) | Israel | Longitudinal | 146 | 0.1 | 13 |
| Behavior response paradigm | Feldman et al. (2002) | Israel | Longitudinal | 146 | 3 | 13 |
| Toy exploration task | Feldman et al. (2002) | Israel | Longitudinal | 146 | 6 | 13 |
| Infant behavioural assessment | Wolf et al. (2002) | Netherlands | Longitudinal | 30 | 3 | 9 |

Abbreviation: QI, quality index.

regulation in neonates, $M_{age} = 0.79$ months, while the FFSF was the observational measure used by more studies to assess emotional and behavioural regulation in older infants, $M_{age} = 5.64$ months. All the studies using the FFSF measured infant self-regulation during the interaction between the infant and the mother. Besides these measures, the Neonatal Behavior Assessment Scale (NBAS; Brazelton & Nugent, 1995) and the Bayley Scales of Infant Development—II (BSID-II; Bayley, 1993) were also used by more than one study. The NBAS was used in six studies to assess behavioural regulation in neonates, $M_{age} = 0.35$ months, and the BSID-II was used in three studies to assess emotional and behavioural regulation in older infants, $M_{age} = 4.8$ months.

### 3.3.2 | Parent-reported measures

Table 2 summarizes the parent-reported behavioural measures to assess infant self-regulation during the first 12 months of life. All the studies using parent-reported measures presented a longitudinal design. The studies' sample size ranged between 29 and 7450 infants, $M_{sample} = 907.43$ infants (Milgrom et al., 2015; Radesky et al., 2014). Infants' ages ranged between two and 12 months, $M_{age} = 6.69$ months. A total of six different parent-reported measures were identified in the 21 studies assessing emotional, cognitive, and behavioural regulation (see Table 2). All

**TABLE 2** Parent-reported measures to assess infant self-regulation during the first 12 months of life.

| Self-regulation measure | First author (year of publication) | Country | Design | *N* | Age (months) | QI |
|---|---|---|---|---|---|---|
| Infant Behavior Questionnaire revised—very short form | Ju et al. (2022) | USA | Longitudinal | 84 | 3 | 12 |
| Infant Behavior Questionnaire revised—short form | Kajanoja et al. (2022) | Finland | Longitudinal | 1173 | 6 | 11 |
| Infant Behavior Questionnaire revised | Mattera et al. (2022) | USA | Longitudinal | 64 | 2 | 10 |
| Infant Behavior Questionnaire revised—very short form | Bates et al. (2021) | USA | Longitudinal | 168 | 10.5 | 10 |
| Infant Behavior Questionnaire revised | Koenraads et al. (2021) | Netherlands | Longitudinal | 3421 | 6 | 12 |
| Infant Behavior Questionnaire revised | Pingeton et al. (2021) | USA | Longitudinal | 90 | 4 | 10 |
| Infant Behavior Questionnaire revised—short form | Morales-Muñoz et al. (2020) | Finland | Longitudinal | 1415 | 6 | 12 |
| Infant Behavior Questionnaire revised | Sun et al. (2022) | USA | Longitudinal | 166 | 3, 6, 12 | 13 |
| Infant Behavior Questionnaire revised—short form | Freedman et al. (2019) | USA | Longitudinal | 136 | 12 | 10 |
| Infant Behavior Questionnaire revised—Short Form | Jones et al. (2018) | USA | Longitudinal | 111 | 4 | 12 |
| Infant Behavior Questionnaire revised | Bush et al. (2017) | USA | Longitudinal | 151 | 4 | 14 |
| Infant Behavior Questionnaire revised | van deWeijer-Bergsma et al. (2016) | Netherlands | Longitudinal | 76 | 7 | 12 |
| Infant Behavior Questionnaire revised | Anzman-Frasca et al. (2013) | USA | Longitudinal | 110 | 12 | 13 |
| Infant Behavior Questionnaire revised | Martinos et al. (2012) | UK | Longitudinal | 60 | 7.5 | 10 |
| Ages and Stages Questionnaire: Social emotional | Twohig et al. (2021) | Ireland | Longitudinal | 61 | 6, 12 | 9 |
| Ages and Stages Questionnaire: Social emotional | Milgrom et al. (2015) | Australia | Longitudinal | 29 | 9 | 11 |
| Ages and Stages Questionnaire: Social emotional | van den Heuvel et al. (2015) | Netherlands | Longitudinal | 90 | 9.7 | 11 |
| Infant sleep activity record | Öztürk Dönmez and Bayik Temel (2019) | Turkey | Longitudinal | 42 | 1, 2, 3, 6 | 9 |
| Australian Temperament Scales | Williams et al. (2017) | Australia | Longitudinal | 4109 | 8.8 | 12 |
| Infant toddler symptom checklist | Radesky et al. (2014) | USA | Longitudinal | 7450 | 9 | 13 |
| Regulatory disorders checklist | Dale et al. (2011) | USA | Longitudinal | 50 | 9 | 10 |

Abbreviation: QI = Quality index.

**TABLE 3** Physiological measures to assess infant self-regulation during the first 12 months of life.

| Self-regulation measure | First author (year of publication) | Country | Design | *N* | Age (months) | QI |
|---|---|---|---|---|---|---|
| Vagal regulation through respiratory sinus arrhythmia | Lan et al. (2022) | China | Cross-sectional | 204 | 6.6 | 11 |
| Vagal regulation through respiratory sinus arrhythmia | Abney et al. (2021) | USA | Cross-sectional | 114 | 5 | 10 |
| Vagal regulation through respiratory sinus arrhythmia | Rudd et al. (2021) | USA | Longitudinal | 60 | 6 | 10 |
| Vagal regulation through respiratory sinus arrhythmia | Lin et al. (2021) | USA | Longitudinal | 78 | 2, 6 | 11 |
| Vagal regulation through respiratory sinus arrhythmia | Busuito et al. (2019) | USA | Cross-sectional | 140 | 6 | 12 |
| Vagal regulation through respiratory sinus arrhythmia | Van Puyvelde et al. (2019) | Belgium | Cross-sectional | 41 | 2.3 | 9 |
| Vagal regulation through respiratory sinus arrhythmia | Jones et al. (2018) | USA | Longitudinal | 111 | 4 | 12 |
| Vagal regulation through respiratory sinus arrhythmia | Busuito et al. (2017) | USA | Cross-sectional | 53 | 6.8 | 11 |
| Vagal regulation through respiratory sinus arrhythmia | Gray et al. (2017) | USA | Longitudinal | 167 | 4 | 12 |
| Vagal regulation through respiratory sinus arrhythmia | Dale et al. (2011) | USA | Longitudinal | 50 | 9 | 10 |
| Vagal regulation through respiratory sinus arrhythmia | Moore et al. (2009) | USA | Cross-sectional | 152 | 6 | 13 |
| Vagal regulation through respiratory sinus arrhythmia | Lester et al. (1996) | USA | Cross-sectional | 44 | 0.1 | 8 |
| Heart rate variability through electrocardiogram | Della Longa et al. (2021) | Italy | Cross-sectional | 30 | 0.1 | 10 |
| Heart rate variability through electrocardiogram | Raghunath et al. (2020) | Singapore | Cross-sectional | 24 | 1.9 | 10 |
| Heart rate variability through electrocardiogram | Busuito et al. (2019) | USA | Cross-sectional | 140 | 6 | 12 |
| Heart rate variability through electrocardiogram | Cevasco-Trotter et al. (2019) | USA | Longitudinal | 60 | 0 | 9 |
| Heart rate variability through electrocardiogram | Jones et al. (2018) | USA | Longitudinal | 111 | 4 | 12 |
| Cortisol reactivity through saliva samples | Thompson et al. (2022) | Mexico | Longitudinal | 240 | 3, 5 | 12 |
| Cortisol reactivity through saliva samples | Erickson et al. (2019) | Mexico | Longitudinal | 50 | 4 | 10 |
| Skin conductance | Busuito et al. (2019) | USA | Cross-sectional | 140 | 6 | 12 |
| Frontal electroencephalogram asymmetry | Smith et al. (2016) | USA | Longitudinal | 65 | 10 | 11 |

Abbreviation: QI = Quality index.

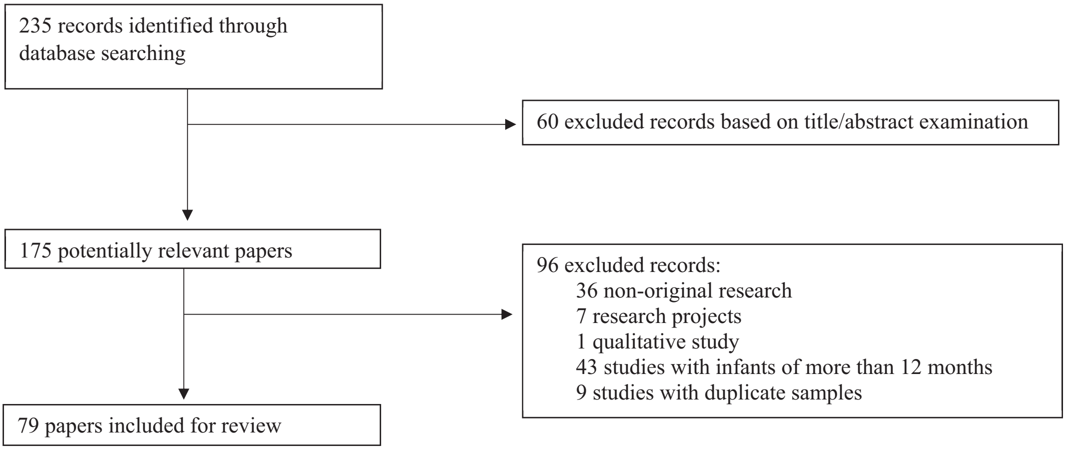


**FIGURE 1** Search strategy flow chart.

the studies used one parent-reported measure and selected the mothers of the infants to complete the parent-reported measures.

The Infant Behavior Questionnaire-Revised (IBQ-R; Gartstein & Rothbart, 2003) was the parent-reported measure used by more studies to assess emotional, cognitive, and behavioural regulation (66.7%; $n = 14$). This measure was used in infants between two and 12 months of age, $M_{age} = 6.56$ months. Besides the IBQ-R, the Ages and Stages Questionnaire: Social Emotional (Squires et al., 2001) was also used in three studies on infants between 6 and 10 months of age (Milgrom et al., 2015; Twohig et al., 2021; van den Heuvel et al., 2015).

### 3.4 | Physiological measures to assess infant self-regulation during the first year of life

Table 3 summarizes the physiological measures to assess infant self-regulation during the first 12 months of life. Studies using physiological measures presented either a longitudinal or a cross-sectional (50%; $n = 9$) design. Studies' sample sizes ranged between 24 and 240 infants, $M_{sample} = 93.50$ infants (Raghunath et al., 2020; Thompson et al., 2022). Infant's age ranged between 0 and 10 months, $M_{age} = 4.39$ months. A total of five different physiological measures were identified in the 18 studies (see Table 3). Most studies used one physiological measure(88.9%; $n = 16$).

Infant's vagal regulation through the recording of respiratory sinus arrhythmia (RSA; Porges, 1985, 2001, 2007) was the physiological measure used by most studies (66.7%; $n = 12$). This measure was used in infants between 0.1 and 9 months of age, $M_{age} = 4.91$ months. More than half of these studies assessed infant's vagal regulation during the FFSF (58.3%; $n = 7$). Besides the assessment of infant's vagal regulation, heart rate variability through electrocardiogram was also used in five studies.

## 4 | DISCUSSION

This study provided a systematic review of the measures used to assess infant self-regulation during the first 12 months of life. It included 79 studies performed in different countries, over the last two decades, assessing physiological, emotional, cognitive, and behavioural regulation.

### 4.1 | Behavioural versus physiological measures

Infant self-regulation during the first 12 months of life is generally assessed using behavioural measures. The behavioural versus physiological measures used to assess infant self-regulation were found to vary according to the study design, the sample size, and the infant's age. Studies aiming to assess self-regulation in older infants tended to use behavioural measures, specifically parent-reported measures, while studies aiming to assess self-regulation in younger infants tended to use physiological measures (except the study conducted by Smith et al., 2016). These differences found in the measures used could be related to the developmental stage of self-regulation. Physiological and behavioural states are progressively regulated during the first year of life (Bell & Deater-Deckard, 2007; Calkins, 2009). Physiological states are first regulated which promotes further emotional, cognitive, and behavioural regulation (Calkins, 2009; Porges, 2007). This may suggest that physiological regulation can be assessed early in infancy using physiological measures, while emotional, cognitive, and behavioural regulation can be assessed later in infancy using behavioural measures.

### 4.2 | Observational versus parent-reported measures

Behavioural measures to assess infant self-regulation are usually observational. The observational versus parent-reported measures used to assess infant self-regulation were found to vary according to the sample size and infant's age. Studies aiming to assess infant self-regulation since birth used observational measures, while studies aiming to assess self-regulation later in infancy used parent-reported measures. This could be because there are no parent-reported measures designed to be applied in infants less than 3 months of age, so only observational measures could be used.

#### 4.2.1 | Observational measures

Several observational measures were identified, assessing infant self-regulation from birth to 12 months of infant's life. The observational measure used was found to vary according to infant's age. Studies aiming to assess behavioural regulation in neonates tended to use the NNS (Lester & Tronick, 2004) or the NBAS (Brazelton & Nugent, 1995), while studies aiming to assess emotional and behavioural regulation in older infants tended to use the FFSF (Tronick et al., 1978). Few studies use more than one observational measure to assess infant self-regulation. It is important to note that all these studies (Brandes-Aitken et al., 2019; Hendry et al., 2022; Wiebe et al., 2014) assessed self-regulation later in infancy, which allows a more complex assessment of infant self-regulation, including emotional, cognitive, and behavioural regulation.

The NNS and the NBAS were designed to assess the neurobehavioural performance in neonates, and both include specific tasks to assess behavioural regulation, allowing the observation of several regulatory behaviours in the neonate (e.g., Brazelton & Nugent, 1995; Lester & Tronick, 2004). Likewise, the FFSF (Tronick et al., 1978) includes specific tasks to assess emotional and behavioural regulation in older infants. The FFSF is performed during parent–infant interaction and is comprised of three brief segments that challenge infant self-regulation in response to temporary parental emotional unavailability (Tronick, 1989; Weinberg & Tronick, 1996). This procedure allows the observation of several behaviours (e.g., avoidance, gaze aversion, and attention seeking) that the infant can manifest to regulate the distress elicited during the FFSF (e.g., Conradt et al., 2015; MacLean et al., 2014; Noe et al., 2015).

#### 4.2.2 | Parent-reported measures

Few studies used parent-reported measures to assess infant self-regulation and few parent-reported measures were identified. Contrarily to observational measures, the parent-reported measure used did not vary according to infant's age. Regardless of infant's age, studies assessing infant emotional, cognitive, and behavioural regulation with parent-reported measures tended to use the IBQ-R (Gartstein & Rothbart, 2003).

The IBQ-R (Gartstein & Rothbart, 2003) allows the assessment of infant orienting and self-soothing behaviours. It is a parent-reported measure designed to assess temperament in infants from 3 to 12 months of age and evidence of good psychometric characteristics was provided when using the IBQ-R in infants younger than three months of age (Dias et al., 2021). Although the IBQ-R was designed to assess infant temperament, this instrument was the most used parent-reported measure in the reviewed studies to assess infant self-regulation. Specifically, the orienting regulation dimension of the IBQ-R allows the assessment of infant orienting and self-soothing behaviours, observed by parents in daily routine situations and across several contexts. Self-regulation theory (Rothbart et al., 2011) suggested that self-regulation is conceptually related to temperament. One of the major functions of self-regulation is the modulation of temperament characteristics. On the other hand, temperament reflects individual differences in emotional, motor, and attentional reactivity as well as individual differences in the regulation of this reactivity (Dias et al., 2021; Rothbart et al., 2011).

## 4.3 | Physiological measures

Few studies used physiological measures to assess infant self-regulation and five physiological measures were identified. Contrary to the studies using behavioural measures, the physiological measure used did not vary according to infant's age. Regardless of infant's age, studies tended to use vagal regulation through RSA as a physiological measure of infant self-regulation. The RSA is a derivative of the parasympathetic nervous system (PNS) activity and is an index of heart rate variability in the respiratory frequency range (Porges, 1985). The autonomic nervous system comprises both a sympathetic (SNS) branch, which initiates physiological arousal, and a PNS branch, which modulates SNS input to the heart and other target organs, regulating recovery and restoring autonomic homeostasis (Porges, 2001, 2007). Vagal tone is a component of PNS control and is a major physiological marker of self-regulation (Porges, 2001, 2007). Vagal regulation refers to the adequate activation or inhibition of vagal tone. Vagal tone is inhibited when the environment presents some challenges which increases heart rate and promotes self-regulatory behaviours. When environmental challenges ceased, vagal tone is activated (Beauchaine et al., 2007; Porges, 2001, 2007). Vagal inhibition can be detected by decreases in the amplitude of RSA during situations that can challenge infant behavioural self-regulation (e.g., Busuito & Moore, 2017; Gray et al., 2017). Most of the studies assessed infant's vagal regulation during FFSF, one of the most used behavioural observational measures to assess infant self-regulation.

# 5 | CONCLUSION

Contrasts were identified when comparing (1) studies using behavioural or physiological measures and (2) behavioural studies using observational or parent-reported measures. Measures used to assess infant self-regulation during the first 12 months of life are generally selected according to the study design, the sample size, and mainly infant's age. Studies targeting younger infants used physiological measures and studies targeting older infants used behavioural measures, with observational measures used with younger infants and parental-reported measures used with older infants during the first year of life. Moreover, studies targeting younger infants mostly assessed physiological and behavioural regulation, while studies targeting older infants assessed self-regulation regulation at more complex levels, namely emotional and cognitive regulation.

Both observational and parent-reported measures provide key information to assess infant self-regulation (e.g., Rothbart & Bates, 2006). Observational measures assess infant self-regulation during a specific situation, while parent-reported measures allow the assessment of infant self-regulation in daily routine situations across a variety of contexts where parents have more opportunities to observe the infant. Observational measures can be more adequate to assess infant-self-regulation during a stressful situation, while parent-reported measures can be more adequate to assess self-regulation during and across the days of the infant's life. Combining both observational and parent-reported measures could provide a broader assessment of infant self-regulation.

On the other hand, studies aiming to assess self-regulation earlier in infancy tend to use observational measures. This could be because there are no parent-reported measures designed to be applied to younger infants. Considering the advantages of using parent-reported measures, adapting these measures to assess self-regulation in younger infants could be a major advance to the literature and practice in the field.

Finally, it is important to note that most of the reviewed studies used only one measure and assessed one dimension of infant self-regulation. A self-regulation is conceptually defined as a multidimensional and complex construct with physiological, emotional, cognitive, and behavioural dimensions (Rothbart et al., 2011), including physiological, observational, and parent-reported indicators of self-regulation could represent a major advance in the assessment of infant self-regulation. Moreover, the studies reported good psychometric characteristics on the measures used to assess infant self-regulation. Further studying the psychometric characteristics of both observational and physiological measures, considering self-regulation development level, could advance the assessment of infant self-regulation during the first year of life.

This study identified the behavioural and physiological measures most used to assess infant self-regulation. The NNS (Lester & Tronick, 2004) and the NBAS (Brazelton & Nugent, 1995) were identified as the observational measures most used to assess behavioural regulation in younger infants. While the FFSF (Tronick et al., 1978) was identified as the observational measure most used to assess emotional and behavioural regulation in older infants. The IBQ-R (Gartstein & Rothbart, 2003) was identified as the parent-reported measure most used to assess infant emotional, cognitive, and behavioural regulation. Infant's vagal regulation through RSA was identified as the measure most used to assess infant self-regulation. Although several measures of infant self-regulation were identified, we acknowledge that the search terms used could have limited the inclusion of studies not using the term "self-regulation." Future systemic reviews could address this issue.

Studying self-regulation early in infancy is a major issue to understand self-regulatory processes in developing infants and to identify infants with self-regulation difficulties. The present systematic review contributes to research and practice on infant self-regulation, assisting researchers and clinical practitioners to select adequate measures to assess infant self-regulation at different ages and in diverse circumstances. When measuring self-regulation is important to consider infant's age, to fit the measurement procedures with the self-regulation development level, that is how self-regulation is established and manifested.

## AUTHOR CONTRIBUTIONS

**Tiago Miguel Pinto:** Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; writing – original draft. **Bárbara Figueiredo:** Conceptualization; funding acquisition; methodology; project administration; supervision; validation; writing – review and editing.

## ACKNOWLEDGEMENTS

This study was conducted at Psychology Research Centre (UID/PSI/01662/2013), University of Minho, and supported by the Portuguese Foundation for Science and Technology and the Portuguese Ministry of Education and Science through national funds and co-financed by FEDER through COMPETE2020 under the PT2020 Partnership Agreement (POCI-01-0145-FEDER-007653). This research was also supported by FEDER Funds through the Programa Operacional Factores de Competitividade—COMPETE and by National Funds through FCT – Fundação para a Ciência e a Tecnologia under the project PTDC/SAU/SAP/116738/2010 and individual grant SFRH/BD/115048/2016. This study was also funded by the Foundation for Science and Technology—FCT (Portuguese Ministry of Science, Technology and Higher Education), under the grant UIDB/05380/2020.

## PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/icd.2414.

## DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated

## ORCID

*Tiago Miguel Pinto* https://orcid.org/0000-0002-7581-8961

## REFERENCES

Aarts, H. (2007). On the emergence of human goal pursuit: The nonconscious regulation and motivation of goals. *Social and Personality Psychology Compass*, *1*, 183–201. https://doi.org/10.1111/j.1751-9004.2007.00014.x

Abney, D. H., daSilva, E. B., & Bertenthal, B. I. (2021). Associations between infant–mother physiological synchrony and 4-and 6-month-old infants' emotion regulation. *Developmental Psychobiology*, *63*(6), e22161. https://doi.org/10.1002/dev.22161

Anzman-Frasca, S., Stifter, C. A., Paul, I. M., & Birch, L. L. (2013). Infant temperament and maternal parenting self-efficacy predict child weight outcomes. *Infant Behavior and Development*, *36*, 494–497. https://doi.org/10.1016/j.infbeh.2013.04.006

Barbosa, M., Beeghly, M., Moreira, J., Tronick, E., & Fuertes, M. (2021). Emerging patterns of infant regulatory behavior in the Still-Face paradigm at 3 and 9 months predict mother-infant attachment at 12 months. *Attachment & Human Development*, *23*(6), 814–830. https://doi.org/10.1080/14616734.2020.1757730

Bargh, J. A., & Morsella, E. (2008). The unconscious mind. *Perspectives on Psychological Science*, *3*, 73–79. https://doi.org/10.1111/j.1745-6916.2008.00064.x

Bates, R. A., Justice, L. M., Salsberry, P. J., Jiang, H., Dynia, J. M., & Singletary, B. (2021). Co-occurring risk and protective factors and regulatory behavior of infants living in low-income homes. *Infant Behavior and Development*, *64*(8), 101598. https://doi.org/10.1016/j.infbeh.2021.101598

Bayley, N. (1993). *Manual for the Bayley Scales of infant development* (2nd ed.). The Psychological Corporation.

Bazhenova, O. V., Plonskaia, O., & Porges, S. W. (2001). Vagal reactivity and affective adjustment in infants during interaction challenges. *Child Development*, *72*, 1314–1326. https://doi.org/10.1111/1467-8624.00350

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology*, *74*, 174–184. https://doi.org/10.1016/j.biopsycho.2005.08.008

Beauchamp, K. G., Lowe, J., Schrader, R. M., Shrestha, S., Aragón, C., Moss, N., & Bakhireva, L. N. (2020). Self-regulation and emotional reactivity in infants with prenatal exposure to opioids and alcohol. *Early Human Development*, *148*(9), 105119. https://doi.org/10.1016/j.earlhumdev.2020.105119

Bell, M. A., & Deater-Deckard, K. (2007). Biological systems and the development of self-regulation: Integrating behavior, genetics, and psychophysiology. *Journal of Developmental & Behavioral Pediatrics*, *28*, 409–420. https://doi.org/10.1097/DBP.0b013e3181131fc7

Brandes-Aitken, A., Braren, S., Swingler, M., Voegtline, K., & Blair, C. (2019). Sustained attention in infancy: A foundation for the development of multiple aspects of self-regulation for children in poverty. *Journal of Experimental Child Psychology*, *184*(8), 192–209. https://doi.org/10.1016/j.jecp.2019.04.006

Brazelton, T. B., & Nugent, J. K. (1995). *Neonatal Behavioral Assessment Scale* (Vol. No. 137). Cambridge University Press.

Bush, N. R., Jones-Mason, K., Coccia, M., Caron, Z., Alkon, A., Thomas, M., & Epel, E. S. (2017). Effects of pre-and postnatal maternal stress on infant temperament and autonomic nervous system reactivity and regulation in a diverse, low-income population. *Development and Psychopathology*, *29*, 1553–1571. https://doi.org/10.1017/S0954579417001237

Busuito, A., & Moore, G. A. (2017). Dyadic flexibility mediates the relation between parent conflict and infants' vagal reactivity during the Face-to-Face Still-Face. *Developmental Psychobiology*, *59*, 449–459. https://doi.org/10.1002/dev.21508

Busuito, A., Quigley, K. M., Moore, G. A., Voegtline, K. M., & DiPietro, J. A. (2019). In sync: Physiological correlates of behavioral synchrony in infants and mothers. *Developmental Psychology*, *55*(5), 1034–1045. https://doi.org/10.1037/dev0000689

Calkins, S. D. (2009). Regulatory competence and early disruptive behavior problems: The role of physiological regulation. In S. L. Olson & A. J. Sameroff (Eds.), *Biopsychosocial regulatory process in the development of childhood behavioral problems* (pp. 86–115). Cambridge University Press.

Cevasco-Trotter, A. M., Hamm, E. L., Yang, X., & Parton, J. (2019). Multimodal neurological enhancement intervention for self-regulation in premature infants. *Advances in Neonatal Care*, *19*(4), E3–E11. https://doi.org/10.1097/ANC.0000000000000595

Chow, S. M., Haltigan, J. D., & Messinger, D. S. (2010). Dynamic infant–parent affect coupling during the face-to-face/still-face. *Emotion*, *10*, 101–114. https://doi.org/10.1037/a0017824

Cole, P. M., Martin, S. E., & Dennis, T. A. (2004). Emotion regulation as a scientific construct: Methodological challenges and directions for child development research. *Child Development*, *75*, 317–333. https://doi.org/10.1111/j.14678624.2004.00673.x

Conradt, E., Fei, M., LaGasse, L., Tronick, E., Guerin, D., Gorman, D., & Lester, B. M. (2015). Prenatal predictors of infant self-regulation: The contributions of placental DNA methylation of NR3C1 and neuroendocrine activity. *Frontiers in Behavioral Neuroscience*, *9*, 130. https://doi.org/10.3389/fnbeh.2015.00130

Conradt, E., Lester, B. M., Appleton, A. A., Armstrong, D. A., & Marsit, C. J. (2013). The roles of DNA methylation of NR3C1 and 11β-HSD2 and exposure to maternal mood disorder in utero on newborn neurobehavior. *Epigenetics*, *8*, 1321–1329. https://doi.org/10.4161/epi.26634

Coyle, M. G., Salisbury, A. L., Lester, B. M., Jones, H. E., Lin, H., Graf-Rohrmeister, K., & Fischer, G. (2012). Neonatal neurobehavior effects following buprenorphine versus methadone exposure. *Addiction*, *107*, 63–73. https://doi.org/10.1111/j.1360-0443.2012.04040.x

Crandell, L. E., Patrick, M. P., & Hobson, R. P. (2003). 'Still-face' interactions between mothers with borderline personality disorder and their 2-month-old infants. *The British Journal of Psychiatry*, *183*, 239–247. https://doi.org/10.1192/bjp.183.3.239

Crockenberg, S. C., & Leerkes, E. M. (2004). Infant and maternal behaviors regulate infant reactivity to novelty at 6 months. *Developmental Psychology*, *40*, 1123–1132. https://doi.org/10.1037/0012-1649.40.6.1123

Dale, L. P., O'Hara, E. A., Keen, J., & Porges, S. W. (2011). Infant regulatory disorders: Temperamental, physiological, and behavioral features. *Journal of Developmental and Behavioral Pediatrics*, *32*, 216–224. https://doi.org/10.1097/DBP.0b013e3181e32c4f

de l'Etoile, S. K. (2015). Self-regulation and infant-directed singing in infants with Down syndrome. *The Journal of Music Therapy*, *52*, 195–220. https://doi.org/10.1093/jmt/thv003

Della Longa, L., Dragovic, D., & Farroni, T. (2021). In touch with the heartbeat: newborns' cardiac sensitivity to affective and non-affective touch. *International Journal of Environmental Research and Public Health*, *18*(5), 2212. https://doi.org/10.3390/ijerph18052212

Dias, C. C., Costa, R., Pinto, T. M., & Figueiredo, B. (2021). The Infant Behavior Questionnaire – Revised: psychometric properties at 2 weeks, 3, 6 and 12 months of life. *Early Human Development*, *153*, 105290. https://doi.org/10.1016/j.earlhumdev.2020.105290

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of Epidemiology & Community Health*, *52*, 377–384. https://doi.org/10.1136/jech.52.6.377

Egmose, I., Nørkær, E., Stuart, A. C., Blurton, S. P., Køppe, S., & Væver, M. S. (2021). Temporal coordination between maternal looming and infant gaze in depressed and nondepressed dyads: A bootstrapping approach. *Infant Behavior and Development*, *62*(2), 101523. https://doi.org/10.1016/j.infbeh.2020.101523

Eisenberg, N., Liew, J., & Pidada, S. U. (2004). The longitudinal relations of regulation and emotionality to quality of Indonesian children's socioemotional functioning. *Developmental Psychology*, *40*, 790–804. https://doi.org/10.1037/0012-1649.40.5.790

El-Sheikh, M., Kouros, C. D., Erath, S., Cummings, E. M., Keller, P., & Staton, L. (2009). Marital conflict and children's externalizing behavior: Pathways involving interactions between parasympathetic and sympathetic nervous system activity. *Monographs of the Society for Research in Child Development*, *74*(1), 1–79. https://doi.org/10.1111/j.1540-5834.2009.00501.x

Erickson, S. J., Kubinec, N., Vaccaro, S., Moss, N., Avila-Rieger, R., Rowland, A., & Lowe, J. R. (2021). The role of maternal interactive behavior and gestational age in predicting infant affect during the Still-Face Paradigm. *Early Human Development*, *163*(12), 105485. https://doi.org/10.1016/j.earlhumdev.2021.105485

Erickson, S. J., Kubinec, N., Vaccaro, S., Moss, N., Rieger, R., Rowland, A., & Lowe, J. R. (2019). The association between maternal interaction and infant cortisol stress reactivity among preterm and full term infants at 4 months adjusted age. *Infant Behavior and Development*, *57*(11), 101342. https://doi.org/10.1016/j.infbeh.2019.101342

Feldman, R., Weller, A., Sirota, L., & Eidelman, A. I. (2002). Skin-to-Skin contact (Kangaroo care) promotes self-regulation in premature infants: sleep-wake cyclicity, arousal modulation, and sustained exploration. *Developmental Psychology*, *38*, 194–207. https://doi.org/10.1037/0012-1649.38.2.194

Ferreira, A. M., & Bergamasco, N. H. (2010). Behavioral analysis of preterm neonates included in a tactile and kinesthetic stimulation program during hospitalization. *Brazilian Journal of Physical Therapy*, *14*, 141–148. https://doi.org/10.1590/S1413-35552010005000002

Freedman, R., Hunter, S. K., Law, A. J., Wagner, B. D., D'Alessandro, A., Christians, U., & Hoffman, M. C. (2019). Higher gestational choline levels in maternal infection are protective for infant brain development. *The Journal of Pediatrics*, *208*(5), 198–206. https://doi.org/10.1016/j.jpeds.2018.12.010

Gartstein, M. A., & Rothbart, M. K. (2003). Studying infant temperament via the Revised Infant Behavior Questionnaire. *Infant Behavior and Development*, *26*, 64–86. https://doi.org/10.1016/S0163-6383(02)00169-8

Gray, S. A., Jones, C. W., Theall, K. P., Glackin, E., & Drury, S. S. (2017). Thinking across generations: unique contributions of maternal early life and prenatal stress to infant physiology. *Journal of the American Academy of Child & Adolescent Psychiatry*, *56*, 922–929. https://doi.org/10.1016/j.jaac.2017.09.001

Graziano, P., & Derefinko, K. (2013). Cardiac vagal control and children's adaptive functioning: A meta-analysis. *Biological Psychology*, *94*, 22–37. https://doi.org/10.1016/j.biopsycho.2013.04.011

Grenier, I. R., Bigsby, R., Vergara, E. R., & Lester, B. M. (2003). Comparison of motor self-regulatory and stress behaviors of preterm infants across body positions. *American Journal of Occupational Therapy*, *57*, 289–297. https://doi.org/10.5014/ajot.57.3.289

Ham, J., & Tronick, E. D. (2006). Infant resilience to the stress of the still-face: Infant and maternal psychophysiology are related. *Annals of the New York Academy of Sciences*, *1094*, 297–302. https://doi.org/10.1196/annals.1376.038

Hendry, A., Greenhalgh, I., Bailey, R., Fiske, A., Dvergsdal, H., & Holmboe, K. (2022). Development of directed global inhibition, competitive inhibition and behavioural inhibition during the transition between infancy and toddlerhood. *Developmental Science*, *25*(5), e13193. https://doi.org/10.1111/desc.13193

Hernández-Martínez, C., Arija, V., Balaguer, A., Cavallé, P., & Canals, J. (2008). Do the emotional states of pregnant women affect neonatal behaviour? *Early Human Development*, *84*, 745–750. https://doi.org/10.1016/j.earlhumdev.2008.05.002

Jones, C. W., Gray, S. A., Theall, K. P., & Drury, S. S. (2018). Polymorphic variation in the SLC5A7 gene influences infant autonomic reactivity and self-regulation: A neurobiological model for ANS stress responsivity and infant temperament. *Psychoneuroendocrinology*, *97*, 28–36. https://doi.org/10.1016/j.psyneuen.2018.06.019

Ju, S., Iwinski, S., Fiese, B. H., McBride, B. A., & Bost, K. K. (2022). Infant temperament and mealtime distractions as predictors of preschool Children's bite speed during family mealtime. *Appetite*, *177*(10), 106157. https://doi.org/10.1016/j.appet.2022.106157

Kahya, Y., Uluç, S., & Yusuf, K. (2022). The bidirectional view of mother-infant interaction by gaze and facial affect. *Turkish Journal of Psychiatry*, *33*(1), 32–43. https://doi.org/10.5080/u25794

Kajanoja, J., Nolvi, S., Kantojärvi, K., Karlsson, L., Paunio, T., & Karlsson, H. (2022). Oxytocin receptor genotype moderates the association between maternal prenatal stress and infant early self-regulation. *Psychoneuroendocrinology*, *138*(4), 105669. https://doi.org/10.1016/j.psyneuen.2022.105669

Koenraads, S. P., Jansen, P. W., Baatenburg de Jong, R. J., van der Schroeff, M. P., & Franken, M. C. (2021). Bidirectional associations of childhood stuttering with behavior and temperament. *Journal of Speech, Language, and Hearing Research*, *64*(12), 4563–4579. https://doi.org/10.1044/2021_JSLHR-20-00252

Lan, Q., Li, H., Wang, L., & Chang, S. (2022). Breastfeeding duration and vagal regulation of infants and mothers. *Early Human Development*, *171*(8), 105620. https://doi.org/10.1016/j.earlhumdev.2022.105620

Lester, B. M., Boukydis, C. Z., & LaGasse, L. (1996). Cardiorespiratory reactivity during the Brazelton Scale in term and preterm infants. *Journal of Pediatric Psychology*, *21*, 771–783. https://doi.org/10.1093/jpepsy/21.6.771

Lester, B., & Tronick, E. (2004). The Neonatal Intensive Care Unit Network Neurobehavioral Scale. *Pediatrics*, *113*-(Suppl. 3, Pt.2), 631–695.

Liaw, J. J., Yang, L., Chou, H. L., Yang, M. H., & Chao, S. C. (2010). Relationships between nurse care-giving behaviours and preterm infant responses during bathing: a preliminary study. *Journal of Clinical Nursing*, *19*, 89–99. https://doi.org/10.1111/j.1365-2702.2009.03038.x

Lin, B., Crnic, K. A., Luecken, L. J., & Gonzales, N. A. (2014). Maternal prenatal stress and infant regulatory capacity in Mexican Americans. *Infant Behavior and Development*, *37*, 571–582. https://doi.org/10.1016/j.infbeh.2014.07.001

Lin, B., Yeo, A. J., Luecken, L. J., & Roubinov, D. S. (2021). Effects of maternal and paternal postnatal depressive symptoms on infants' parasympathetic regulation in low-income. *Developmental Psychobiology*, *63*(5), 1436–1448. https://doi.org/10.1002/dev.22073

Lundqvist-Persson, C. (2001). Correlation between level of self-regulation in the newborn infant and developmental status at two years of age. *Acta Paediatrica*, *90*, 345–350. https://doi.org/10.1111/j.1651-2227.2001.tb00316.x

Lundqvist-Persson, C., Lau, G., Nordin, P., Bona, E., & Sabel, K. G. (2012). Preterm infants' early developmental status is associated with later developmental outcome. *Acta Paediatrica*, *101*, 172–178. https://doi.org/10.1111/j.1651-2227.2011.02442.x

MacLean, P. C., Rynes, K. N., Aragón, C., Caprihan, A., Phillips, J. P., & Lowe, J. R. (2014). Mother–infant mutual eye gaze supports emotion regulation in infancy during the still-face paradigm. *Infant Behavior and Development*, *37*, 512–522. https://doi.org/10.1016/j.infbeh.2014.06.008

Martinos, M., Matheson, A., & de Haan, M. (2012). Links between infant temperament and neurophysiological measures of attention to happy and fearful faces. *Journal of Child Psychology and Psychiatry*, *53*, 1118–1127. https://doi.org/10.1111/j.1469-7610.2012.02599.x

Mattera, J. A., Waters, S. F., Lee, S., Connolly, C. P., & Gartstein, M. A. (2022). Prenatal internalizing symptoms as a mediator linking maternal adverse childhood experiences with infant temperament. *Early Human Development*, *168*(5), 105577. https://doi.org/10.1016/j.earlhumdev.2022.105577

McGowan, E. C., Hofheimer, J. A., O'Shea, T. M., Carter, B. S., Helderman, J., Neal, C. R., & Lester, B. M. (2020). Sociodemographic and medical influences on neurobehavioral patterns in preterm infants: A multi-center study. *Early Human Development*, *142*(3), 104954. https://doi.org/10.1016/j.earlhumdev.2020.104954

McManus, B. M., Blanchard, Y., Murphy, N. J., & Nugent, J. K. (2020). The effects of the Newborn Behavioral Observations (NBO) system in early intervention: A multisite randomized controlled trial. *Infant Mental Health Journal*, *41*(6), 757–769. https://doi.org/10.1002/imhj.21882

Milgrom, J., Holt, C., Holt, C. J., Ross, J., Ericksen, J., & Gemmill, A. W. (2015). Feasibility study and pilot randomised trial of an antenatal depression treatment with infant follow-up. *Archives of Women's Mental Health*, *18*, 717–730. https://doi.org/10.1007/s00737-015-0512-5

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine*, *151*, 264–269. https://doi.org/10.1016/j.ijsu.2010.02.007

Montirosso, R., Borgatti, R., Trojan, S., Zanini, R., & Tronick, E. (2010). A comparison of dyadic interactions and coping with still-face in healthy pre-term and full-term infants. *British Journal of Developmental Psychology*, *28*, 347–368. https://doi.org/10.1348/026151009X416429

Moore, G. A., Hill-Soderlund, A. L., Propper, C. B., Calkins, S. D., Mills-Koonce, W. R., & Cox, M. J. (2009). Mother–infant vagal regulation in the face-to-face still-face paradigm is moderated by maternal sensitivity. *Child Development*, *80*, 209–223. https://doi.org/10.1111/j.1467-8624.2008.01255.x

Morales, M., Mundy, P., Crowson, M., Neal, A. R., & Delgado, C. (2005). Individual differences in infant attention skills, joint attention, and emotion regulation behaviour. *International Journal of Behavioral Development*, *29*, 259–263. https://doi.org/10.1080/01650250444000432

Morales-Muñoz, I., Nolvi, S., Virta, M., Karlsson, H., Paavonen, E. J., & Karlsson, L. (2020). The longitudinal associations between temperament and sleep during the first year of life. *Infant Behavior and Development*, *61*(11), 101485. https://doi.org/10.1016/j.infbeh.2020.101485

Nigg, J. T. (2017). Annual Research Review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry*, *58*(4), 361–383. https://doi.org/10.1111/jcpp.12675

Noe, D., Schluckwerder, S., & Reck, C. (2015). Influence of dyadic matching of affect on infant self-regulation. *Psychopathology*, *48*, 173–183. https://doi.org/10.1159/000376586

Öztürk Dönmez, R., & Bayik Temel, A. (2019). Effect of soothing techniques on infants' self-regulation behaviors (sleeping, crying, feeding): A randomized controlled study. *Japan Journal of Nursing Science*, *16*(4), 407–419. https://doi.org/10.1111/jjns.12250

Perry, N. B., Calkins, S. D., & Bell, M. A. (2016). Indirect effects of maternal sensitivity on infant emotion regulation behaviors: The role of vagal withdrawal. *Infancy*, *21*, 128–153. https://doi.org/10.1111/infa.12101

Pineda, R. G., Tjoeng, T. H., Vavasseur, C., Kidokoro, H., Neil, J. J., & Inder, T. (2013). Patterns of altered neurobehavior in preterm infants within the neonatal intensive care unit. *The Journal of Pediatrics*, *162*, 470–476. https://doi.org/10.1016/j.jpeds.2012.08.011

Pingeton, B. C., Goodman, S. H., & Monk, C. (2021). Prenatal origins of temperament: Fetal cardiac development & infant surgency, negative affectivity, and regulation/orienting. *Infant Behavior and Development*, *65*(11), 101643. https://doi.org/10.1016/j.infbeh.2021.101643

Planalp, E. M., Nowak, A. L., Tran, D., Lefever, J. B., & Braungart-Rieker, J. M. (2021). Positive parenting, parenting stress, and child self-regulation patterns differ across maternal demographic risk. *Journal of Family Psychology*, *36*(5), 713–724. https://doi.org/10.1037/fam0000934

Porges, S. W. (1985). *Method and apparatus for evaluating rhythmic oscillations in a periodic physiological response system (U.S. Patent No. 4510944)*. U.S. Patent and Trademark Office.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology*, *42*, 123–146. https://doi.org/10.1016/S0167-8760(01)00162-3

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology*, *74*, 116–143. https://doi.org/10.1016/j.biopsycho.2006.06.009

Radesky, J. S., Silverstein, M., Zuckerman, B., & Christakis, D. A. (2014). Infant self-regulation and early childhood media exposure. *Pediatrics*, *133*, e1172–e1178. https://doi.org/10.1542/peds.2013-2367

Raghunath, B. L., Azhari, A., Bornstein, M. H., Setoh, P., & Esposito, G. (2020). Experimental manipulation of maternal proximity during short sequences of sleep and infant calming response. *Infant Behavior and Development*, *59*(5), 101426. https://doi.org/10.1016/j.infbeh.2020.101426

Rosenblum, K. L., McDonough, S., Muzik, M., Miller, A., & Sameroff, A. (2002). Maternal representations of the infant: Associations with infant response to the still face. *Child Development*, *73*, 999–1015. https://doi.org/10.1111/1467-8624.00453

Rothbart, M. K., & Bates, J. E. (2006). *Handbook of child psychology*: *Vol*. *3*. *social*, *emotional*, *and personality development*. In W. Damon, R. Lerner, & N. Eisenberg (Eds.), *Temperament* (6th ed., pp. 99–106). Wiley.

Rothbart, M. K., Ellis, L. K., & Posner, M. I. (2011). Temperament and self-regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation: research, theory, and applications* (pp. 441–460). Guilford Press.

Rothbart, M. K., Ziaie, H., & O'Boyle, C. G. (1992). Self-regulation and emotion in infancy. *New Directions for Child and Adolescent Development*, *1992*, 7–23. https://doi.org/10.1002/cd.23219925503

Rudd, K. L., Alkon, A., Abrams, B., & Bush, N. R. (2021). Infant weight-for-length gain associated with autonomic nervous system reactivity. *Pediatric Research*, *90*(2), 472–478. https://doi.org/10.1038/s41390-020-01246-z

Salisbury, A. L., Lester, B. M., Seifer, R., LaGasse, L., Bauer, C. R., Shankaran, S., & Poole, K. (2007). Prenatal cocaine use and maternal depression: effects on infant neurobehavior. *Neurotoxicology and Teratology*, *29*, 331–340. https://doi.org/10.1016/j.ntt.2006.12.001

Salisbury, A. L., O'Grady, K. E., Battle, C. L., Wisner, K. L., Anderson, G. M., Stroud, L. R., & Lester, B. M. (2015). The roles of maternal depression, serotonin reuptake inhibitor treatment, and concomitant benzodiazepine use on infant neurobehavioral functioning over the first postnatal month. *American Journal of Psychiatry*, *173*, 147–157. https://doi.org/10.1176/appi.ajp.2015.14080989

Sheese, B. E., Rothbart, M. K., Posner, M. I., White, L. K., & Fraundorf, S. H. (2008). Executive attention and self-regulation in infancy. *Infant Behavior and Development*, *31*, 501–510. https://doi.org/10.1016/j.infbeh.2008.02.001

Sheese, B. E., Voelker, P., Posner, M. I., & Rothbart, M. K. (2009). Genetic variation influences on the early development of reactive emotions and their regulation by attention. *Cognitive Neuropsychiatry*, *14*, 332–355. https://doi.org/10.1080/13546800902844064

Shoaff, J. R., Nugent, K., Brazelton, T. B., & Korrick, S. A. (2021). Early infant behavioural correlates of social skills in adolescents. *Paediatric and Perinatal Epidemiology*, *35*(2), 247–256. https://doi.org/10.1111/ppe.12723

Smith, C. L., Diaz, A., Day, K. L., & Bell, M. A. (2016). Infant frontal electroencephalogram asymmetry and negative emotional reactivity as predictors of toddlerhood effortful control. *Journal of Experimental Child Psychology*, *142*, 262–273. https://doi.org/10.1016/j.jecp.2015.09.031

Squires, J., Bricker, D., Heo, K., & Twombly, E. (2001). Identification of social-emotional problems in young children using a parent-completed screening measure. *Early Childhood Research Quarterly*, *16*, 405–419. https://doi.org/10.1016/S0885-2006(01)00115-6

Stifter, C. A., & Corey, J. M. (2001). Vagal regulation and observed social behavior in infancy. *Social Development*, *10*, 189–201. https://doi.org/10.1111/1467-9507.00158

Stroud, L. R., Papandonatos, G. D., Salisbury, A. L., Phipps, M. G., Huestis, M. A., Niaura, R., & Lester, B. M. (2016). Epigenetic regulation of placental NR3C1: Mechanism underlying prenatal programming of infant neurobehavior by maternal smoking? *Child Development*, *87*, 49–60. https://doi.org/10.1111/cdev.12482

Stroud, L. R., Paster, R. L., Papandonatos, G. D., Niaura, R., Salisbury, A. L., Battle, C., & Lester, B. (2009). Maternal smoking during pregnancy and newborn neurobehavior: Effects at 10 to 27 days. *The Journal of Pediatrics*, *154*, 10–16. https://doi.org/10.1016/j.jpeds.2008.07.048

Sun, X., Seeley, J. R., & Allen, N. B. (2022). Parental internalizing disorder and the developmental trajectory of infant self-regulation: The moderating role of positive parental behaviors. *Development and Psychopathology*, *34*(1), 1–17. https://doi.org/10.1017/S0954579420001042

Thompson, L. A., Liberty, R., & Corr, A. (2022). "Does your baby watch TV?": The associations between at-home TV watching and laboratory challenge cortisol are different for young infants and their mothers. *Developmental Psychobiology*, *64*(2), e22236. https://doi.org/10.1002/dev.22236

Tronick, E. Z. (1989). Emotions and emotional communication in infants. *American Psychologist*, *44*(2), 112–119. https://doi.org/10.1037/0003-066x.44.2.112

Tronick, E. Z., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child Psychiatry*, *17*, 1–13. https://doi.org/10.1016/S0002-7138(09)62273-1

Twohig, A., Murphy, J. F., McCarthy, A., Segurado, R., Underdown, A., Smyke, A., & Molloy, E. J. (2021). The preterm infant–parent programme for attachment—PIPPA Study: A randomised controlled trial. *Pediatric Research*, *90*(3), 617–624. https://doi.org/10.1038/s41390-020-01262-z

van den Bergh, B. R., & Mennes, M. (2006). Het verband tussen angst bij de moeder in de prenatale fase en zelfregulatie in de adolescentie [in Dutch] [Maternal prenatal anxiety and self-regulation in adolescence]. *Kind en Adolescent*, *1*, 31–43.

van den Heuvel, M. I., Johannes, M. A., Henrichs, J., & Van den Bergh, B. R. H. (2015). Maternal mindfulness during pregnancy and infant socio-emotional development and temperament: the mediating role of maternal anxiety. *Early Human Development*, *91*, 103–108. https://doi.org/10.1016/j.earlhumdev.2014.12.003

Van Puyvelde, M., Gorissen, A. S., Pattyn, N., & McGlone, F. (2019). Does touch matter? The impact of stroking versus non-stroking maternal touch on cardio-respiratory processes in mothers and infants. *Physiology & Behavior*, *207*(8), 55–63. https://doi.org/10.1016/j.physbeh.2019.04.024

Velez, M. L., McConnell, K., Spencer, N., Montoya, L., Tuten, M., & Jansson, L. M. (2018). Prenatal buprenorphine exposure and neonatal neurobehavioral functioning. *Early Human Development*, *117*, 7–14. https://doi.org/10.1016/j.earlhumdev.2017.11.009

Warnock, F. F., Craig, K. D., Bakeman, R., & Castral, T. (2014). Self-regulation (recovery) from pain: association between time-based measures of infant pain behavior and prenatal exposure to maternal depression and anxiety. *The Clinical Journal of Pain*, *30*, 663–671. https://doi.org/10.1097/AJP.0000000000000002

Weinberg, M. K., & Tronick, E. Z. (1996). Infant affective reactions to the resumption of maternal interaction after the still-face. *Child Development*, *67*(3), 905. https://doi.org/10.2307/1131869

Weinberg, M. K., Tronick, E. Z., Cohn, J. F., & Olson, K. L. (1999). Gender differences in emotional expressivity and self-regulation during early infancy. *Developmental Psychology*, *35*, 175–188. https://doi.org/10.1037/0012-1649.35.1.175

Wiebe, S. A., Fang, H., Johnson, C., James, K. E., & Espy, K. A. (2014). Determining the impact of prenatal tobacco exposure on self-regulation at 6 months. *Developmental Psychology*, *50*, 1746–1756. https://doi.org/10.1037/a0035904

Williams, K. E., Berthelsen, D., Walker, S., & Nicholson, J. M. (2017). A developmental cascade model of behavioral sleep problems and emotional and attentional self-regulation across early childhood. *Behavioral Sleep Medicine*, *15*, 1–21. https://doi.org/10.1080/15402002.2015.1065410

Williams, K. E., Nicholson, J. M., Walker, S., & Berthelsen, D. (2016). Early childhood profiles of sleep problems and self-regulation predict later school adjustment. *British Journal of Educational Psychology*, *86*, 331–350. https://doi.org/10.1111/bjep.12109

Wolf, M. J., Koldewijn, K., Beelen, A., Smit, B., Hedlund, R., & De Groot, I. J. M. (2002). Neurobehavioral and developmental profile of very low birthweight preterm infants in early infancy. *Acta Paediatrica*, *91*, 930–938. https://doi.org/10.1111/j.1651-2227.2002.tb02858.x

Yolton, K., Xu, Y., Strauss, D., Altaye, M., Calafat, A. M., & Khoury, J. (2011). Prenatal exposure to bisphenol A and phthalates and infant neurobehavior. *Neurotoxicology and Teratology*, *33*, 558–566. https://doi.org/10.1016/j.ntt.2011.08.003

Zhang, M., Chen, X., Deng, H., & Lu, Z. (2014). Identifying the interaction of maternal sensitivity and two serotonin-related gene polymorphisms on infant self-regulation. *Infant Behavior and Development*, *37*, 606–614. https://doi.org/10.1016/j.infbeh.2014.06.009

**How to cite this article:** Pinto, T. M., & Figueiredo, B. (2023). Measures of infant self-regulation during the first year of life: A systematic review. *Infant and Child Development*, e2414. https://doi.org/10.1002/icd.2414