


REGULAR ARTICLE

The Welch Emotional Connection Screen: validation of a brief mother–infant relational health screen

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ABSTRACT

Aim: The Welch Emotional Connection Screen (WECS), assesses mother–infant Emotional Connection in clinical settings. It includes: Attraction, Vocal Communication, Facial Communication, Sensitivity/Reciprocity and clinical decision of Emotional Connection (yes/no). We tested concurrent and construct validity of the WECS and associations with behavioural and physiological measures in preterm infants.

Methods: Videos from 76 mothers–infants (gestational age 36 weeks) during an in-NICU caregiving paradigm were coded for maternal caregiving behaviour. Videos of mothers–infants were also obtained at 4 months during 10 minutes of face-to-face play (coded with WECS and for maternal positivity and infant social engagement) and the still-face paradigm (coded for infant behavioural approach towards mother; infant electrocardiogram acquired *in vivo*).

Results: WECS maternal scores were positively associated with maternal sensitivity and quality of vocal contact at 36 weeks (caregiving) and maternal positivity at 4 months (face-to-face). WECS infant scores positively correlated with infant social engagement and maternal positivity during face-to-face interactions at 4 months. Infants from emotionally not connected dyads (vs. emotionally connected dyads) displayed autonomic dysregulation and less approach-seeking behaviour towards mother during interactive/play sessions of the still-face paradigm.

Conclusion: This preliminary evidence supports the WECS as a valid screen for rating mother–preterm infant emotional connection associated with healthier infant biobehavioural stress responding.

INTRODUCTION

The health of the mother–infant relationship is of central importance for the social, emotional and physical health of the developing child. Mother–infant interactions are the foundation for organising infant neurobiological, sensory, perceptual, physical, emotional and relational systems (1). Animal models confirm the developmental relevance of early occurring maternal care via postnatal ‘programming’ of behavioural (2), cardiovascular (3), neuroendocrine (4)

and epigenetic (5) systems underlying stress responding. Parallel studies also exist in the human literature. Low-quality maternal caregiving in full-term infants is associated

Abbreviation

E1 (or E2 or E3), Episodes during the still-face paradigm; EC+, Dyad rated as emotionally connected on the WECS; EC–, Dyad rated as emotionally not connected on the WECS; HR, Heart rate; NICU, Neonatal intensive care unit; WECS, Welch Emotional Connection Screen; WECS-M, WECS-Mother; WECS-I, WECS-Infant.

Key notes

- Mother–infant interactions are foundational for infant neurobiological, sensory, perceptual, physical, emotional and relational systems.
- The Welch Emotional Connection Screen (WECS) is a short screen that overcomes limitations of current paediatric measures of mother/infant relational health that rely on either parent-report or lengthy coding systems, or do not correlate with physiology.
- We show that WECS has concurrent and construct validity and that emotional connection correlates with infant biobehavioural responding.

with behavioural, neurological and neuroendocrine effects indicative of dysregulation (6–9).

Infants born prematurely are at increased risk for suboptimal neurodevelopmental outcomes (10), though mother–infant interventions have been shown to improve early neurological development (11) and social, cognitive and behavioural outcomes in these infants (12). Traumatic events, such as hospitalisation in the neonatal intensive care unit (NICU), can disrupt or impair the relationship between mother and infant (12). Given the critical importance of high-quality mother–infant interactions in establishing healthy biobehavioural development in infants (13), identifying at-risk dyads early is of the utmost importance. To address this need, we created the Welch Emotional Connection Screen (WECS) to measure Emotional Connection in mothers and their preterm infants and to identify dyads at-risk for later socioemotional and relational health disorders.

The impetus for the WECS tool came from the observation (Welch) that emotional connection is an assessable phenomenon. The construct of Emotional Connection is defined within our Calming Cycle Theory (14–16). Theoretically, behaviours displayed during close physical face-to-face proximity (eye contact or gaze aversion, physical attraction or avoidance, vocal cooing or distress, reciprocal responsiveness) can be used to determine mutual emotional connection between the two individuals. The observed behaviours are theorised to reflect the autonomic states, as opposed to the cognitive states, of the dyad. According to the theory, early Emotional Connection between mother and infant serves as the foundation for future relationships (14,15). Therefore, assessment of these relational, and hypothesised autonomic-associated, behaviours should determine risk for various socioemotional and relational disorders later in development.

The idea that autonomic regulation is embedded in normal mother–infant interactions is supported by animal research. Hofer posits that within the normal mother–infant interactions there are three main categories of ‘hidden regulators’ associated with the caregiver: behavioural-sensorimotor, thermal-metabolic and nutrient-interoceptive (17). Using animal models to study specific maternal stimuli, he found that warmth, milk and touch had immediate regulatory effects on various physiological activity, including heart rate of the infant (18). He theorised that these regular interactions eventually become associated with biologic rhythms via ‘social entrainment’ (19). Similarly, stimuli emanating from the infant also serve as regulators of maternal physiology (20,21). Thus, physiological *co-regulation* is inherent to optimal mother–infant interactions (22). Our work extends this prior work in a new theoretical construct, Emotional Connection. The WECS provides a measure of the behaviours associated with mother–infant co-regulation, and also provides a way to measure maladaptive patterns, when they occur (16).

This study has two major aims: (i) to validate the WECS instrument; and (ii) to validate the Emotional Connection construct by examining associations between the WECS and infant biobehavioural responding to stress. While

validating the Emotional Connection construct is our central aim, we began by validating the WECS instrument. We did so by establishing convergent validity with other behavioural coding approaches that overlap with behaviours coded on the WECS in order to demonstrate that the WECS is an objective evaluation of readily observable behaviours.

We validated the WECS instrument by examining the associations between WECS scores and the quality of in-unit Maternal Caregiving Behaviour (8,9) at 36-week gestational age. We hypothesised that dimensions including maternal vocal behaviour, quality of touch and sensitivity measured in the NICU prior to discharge would be associated with maternal WECS dimensional ratings at 4-month infant corrected age. We also examined the associations between the WECS dimensional ratings and observed behaviour of mothers and infants, when measured contemporaneously at 4-month corrected age in a face-to-face paradigm using observational software. Specifically, we tracked maternal and infant social behaviours (i.e. gaze, touch, vocalisations and affect) and measured the behaviours using observational software that affords temporal precision. We hypothesised that the WECS dimensional scores would be significantly associated with behavioural indicators tracked with the observational software, including: maternal and infant affect, vocalisations and gaze.

We validated the Emotional Connection construct by comparing mother and infant coding on the WECS with behavioural and autonomic physiological responses of the infants to the still-face paradigm (16). We did this by testing the degree to which Emotional Connection was associated with infant behavioural and autonomic responses, assessed using measures of heart rate and heart rate variability. We hypothesised that relative to dyads rated as not emotionally connected on the WECS (EC–), dyads rated as emotionally connected on the WECS (EC+) would show more approach-seeking behaviour during the interactive/play sessions of the still-face paradigm before and after the stress of the maternal still-face episode. We also hypothesised that relative to infants of EC– dyads, infants of EC+ dyads would show: (i) a healthier autonomic response to the stress of the still-face episode in the still-face paradigm, as evidenced by a pattern of heart rate acceleration and vagal suppression; and, (ii) a healthier physiological recovery in the final episode of the still-face paradigm, as evidenced by a return to baseline, prestress levels for both heart rate and vagal tone.

METHOD

Participants

In this study, 76 mothers and their preterm infants (40 females) from a larger intervention study of preterm infants (23) participated. Of the infants, 37 (48.7%) were first-born and 20 (26.3%) were twins. In the case of twins, only one twin (Twin A) was included in the data reported here.

Table 1 Summary of behavioural measures

Paradigm	Coded behaviour
Welch Emotional Connection Screen (4-month corrected age)	<p><i>Attraction:</i> Gaze, proximity to each other and touch</p> <p><i>Vocal communication:</i> Warmth in vocal tone and amount of vocal behaviour for mother; clear and consistent vocal or behavioural responsiveness for the preverbal infant</p> <p><i>Facial Expressiveness:</i> Use of expressed emotion via the face to establish or maintain a connection, includes expressions of positivity, laughter, joy and empathy</p> <p><i>Sensitivity/Reciprocity:</i> Social sensitivity to each other's expressed emotions or anticipated/identified needs; can include gaze following, reciprocal vocal or facial behaviour or maternal instrumental care that is serving to establish or maintain a connection to one another</p> <p><i>Emotionally connected:</i> The presence (EC+) or absence (EC-) of connection. A dyad cannot receive a 'yes' if one member of the dyad is seeking connection, while the other is rejecting it</p>
Maternal caregiving behaviour in the NICU (36-week gestational age)	<p><i>Maternal sensitivity:</i> Degree to which mother is attentive to infant needs and responded accordingly</p> <p><i>Quality of vocal contact:</i> Degree to which mother uses affectively warm, infant-directed speech when communicating with infant</p> <p><i>Quality of touch:</i> Mother's quality of handling the infant, including gentle, non-intrusive touch</p>
Mother–infant social engagement during face-to-face interaction (4-month corrected age)	<p><i>Maternal positive affect:</i> Proportion of time mother smiled at/laughed with infant</p> <p><i>Infant social engagement:</i> Proportion of time infant spent looking at and vocalising to mother.</p>
Infant responding to the still-face paradigm (4-month corrected age)	<i>Infant approach:</i> Coded in observational software for proportion of time the infant was smiling and gazing at mother before and after the still-face episode (i.e. stressor)

Table 2 Summary of demographic and key observational variables

Variable	N	M	SD
Demographics			
Gestational age at birth	76	30.80	2.28
Birth weight (in grams)	76	1468.50	381.88
Maternal age	76	33.89	4.98
Paternal age	76	37.08	7.04
Key observational variables			
36-Week observation			
Maternal sensitivity	68	5.14	1.14
Quality of vocal contact	68	4.07	1.40
Quality of touch	68	5.07	0.89
4-Month observations			
WECS-Mother	76	10.67	1.56
WECS-Infant	76	8.43	1.96
Maternal positivity	58	0.06	1.02
Infant social engagement	58	0.00	0.76
SFP Infant approach episode 1	48	0.01	1.01
SFP Infant approach episode 2	48	-0.06	0.90
SFP Maternal approach episode 1	48	0.00	1.0
SFP Maternal approach episode 2	48	0.01	1.00
SFP Maternal approach episode 3	48	-0.01	1.00

SFP = still-face paradigm; WECS = Welch Emotional Connection Screen.

Table 1 provides a summary of all behavioural variables and Table 2 presents the descriptive statistics on additional demographic and key variables.

Quality of maternal caregiving behavior (36-week gestational age)

Mothers enrolled in the study were scheduled for a caregiving observation when their infants reached 36-week gestational age ($M = 37.7$, $SD = 3.5$) (24). Mothers were filmed for

20 minutes as they changed their infant's diaper, held their infant (10 minutes), and fed their infant (first five minutes of feed). This session was filmed using a camera affixed to a tripod placed inside the curtained area of the infant's bay in the NICU.

Quality of Maternal Caregiving Behaviour (24) was assessed from the videos taken in-unit using a modified version of the Ainsworth System for Rating Maternal Caregiving Behaviour (25). All scales were rated from 1 (low quality) to 9 (high quality). Ratings for *maternal sensitivity* measured whether the mother was attentive to infant needs and responded accordingly. *Quality of vocal contact* rated the degree to which mothers used affectively warm, infant-directed speech when communicating with their infants. *Quality of touch* rated the mother's quality of handling the infant, including gentle, non-intrusive touch. Two independent raters, who were blind to all other data, were trained by an expert in Ainsworth's maternal sensitivity scales. Inter-rater reliability was achieved by scoring 15 cases in duplicate by two independent raters (average intra-class r 's: maternal sensitivity = 0.98, quality of vocal contact = 0.98, and touch = 0.88).

WECS Coding (4-Month corrected age)

At 4-month corrected age the dyad returned to a research follow-up clinic ($M = 4.42$ months, $SD = 0.57$). The dyad was first filmed during a 10-minute face-to-face interaction, in which the infant was placed in an infant seat. The mother was seated at eye level across from the infant and instructed to interact with her infant as usual.

Emotional Connection was assessed during this 10-minute face-to-face session using the WECS. We developed the WECS in order to quickly and efficiently code four behavioural dimensions associated with Emotional

Connection, including (i) Attraction, (ii) Vocal Communication, (iii) Facial Communication and (iv) Sensitivity/Reciprocity. Each item was rated on a three-point scale, representing low (i), moderate (ii) and high (iii). Although each dimension was assessed separately, for each item, the primary consideration for the observer was whether the behavioural dimension being rated was employed as a means of *establishing or maintaining a connection within the dyad*. Coding was not dependent on frequency or quality of each behavioural dimension rated in isolation. The question the rater was trained to consider was not 'Is this mother engaging in gentle touch/infant-directed speech/gazing at infant?'; but instead: 'Do mother/infant vocal behaviour/touch/affect/proximity reflect connection or not?' Or in the case of sensitivity/reciprocity: 'Are mother and infant reciprocating social bids or not?' Additionally, each of the four behavioural dimensions was rated based on the emotional state of the other member of the dyad. The rater, therefore, was trained to ask; 'Is each behavioral response appropriate to the other's emotional state?' For instance, a mother who was smiling could receive a positive score. But, if mother was smiling while her infant was crying, she received a low score because of the mismatch to the infant's affective state. Likewise, an infant who was not looking at mother, while mother attempted to engage the infant with warm affect and vocal behaviour, received a low score. Such asymmetry in the degree to which one partner engages, while the other does not, when present, is a key indication of the dyad's lack of Emotional Connection.

To score a 3 (or a 1), the behavioural profile must be *clearly present* (or absent). A score of 2 was given when a profile was mixed – i.e. indicators of both high and low scores were observed. *Attraction* was determined based on gaze, proximity to each other and touch. A high score indicates clear attraction to each other, marked by gazing at, leaning into, and touching or reaching for the other. A low score was given when physical avoidance or gaze aversion was manifest. The basis for coding *Vocal Communication* includes rating warmth in vocal tone and amount of vocal behaviour for mother and clear and consistent vocal or behavioural responsiveness for the preverbal infant. Infants and mothers were rated high only if their vocal behaviour was directed to the other in order to connect to each other. Hence, fussing or crying did not necessarily preclude a high score. A low score was given for silence (mother or infant), for lack of responsiveness to the other's vocalisations and/or a negative/harsh tone of voice or narration that is monologue in nature and/or critical of the infant (mother). *Facial Communication* focuses on use of expressed emotion via the face to establish or maintain a connection. A high score was given when appropriate expressions of positivity, laughter, joy and empathy were clearly used to connect to each other. A low score was given when facial affect was flat or negative and when facial affect was not used to establish or maintain a connection with each other. *Sensitivity/Reciprocity* was coded based on mother and infant's social sensitivity to each other's expressed emotions or

anticipated/identified needs and could include gaze-following, reciprocal vocal or facial behaviour, or even maternal instrumental care that was serving to establish or maintain a connection to one another. While maternal sensitivity is a familiar construct, the WECS is novel in that the social sensitivity of the infant is also assessed and included the infant's attending to or initiating and reciprocating overtures, social bids and gaze behaviour.

After observing these behavioural dimensions, the coder made a final decision as to whether the dyad was emotionally connected (yes/no). While this categorical distinction was informed by the recently observed mother–infant interactions, no summing of dimensional scores towards a clinical cut-off was used to make this global assessment. The presence or absence of connection becomes readily discernable after observing the dyad for each of these behavioural dimensions. The final emotionally connected 'yes' (EC+) or emotionally connected 'no' (EC–) determination is inherently dyadic – a dyad cannot receive a 'yes' if one member of the dyad is seeking connection, while the other is rejecting it. In other words, connection is dependent upon the motivation of both. If one is motivated and the other is not, there is no connection.

Mother–infant social engagement (4-month corrected age)

Videos of the 10-minute face-to-face mother–infant play session were coded for social engagement by two independent coders, blind to the WECS ratings. Using Noldus Observer XT (12.0) behavioural observation software, mother and infant social behaviours were separately tracked for each interactant. Mothers and infants were coded in separate passes for behaviours indicative of social engagement. For example, one pass was for maternal positive affect (smiling at/laughing with infant), another pass for infant gaze behaviour (on/off mom) and another for infant vocal behaviour (non-negative vocalisations). These codes were converted into the per cent of the observed duration when target behaviours occurred for longer than one-second, or rate per minute for events lasting less than one-second. A *maternal positive affect* composite was created by converting the per cent of the observed duration and rate per minute values for maternal positive affect to z-scores and averaging the normalised values. For the infant, the scores for per cent of the observed duration and rate per minute for gazing at mother and non-negative vocalisations were used to create an *infant social engagement* composite. Inter-rater reliability was achieved across seven cases coded in duplicate, with intra-class correlations as follows: maternal positive affect = 0.83, infant gaze to mom = 0.86 and infant non-negative vocalisations = 0.97.

Behavioural and physiological responses of infants during the still-face paradigm (4-month corrected age)

Also at 4-month CA, mothers and infants underwent the traditional still-face paradigm (16). For this paradigm, mother was instructed to play with her infant for two minutes (episode 1, E1); cease responding and express a

Table 3 Interrelations among WECS dimensions

	1	2	3	4	5	6	7	8
1. Mother attraction	–	0.67**	0.65**	0.41*	0.40**	0.24*	0.23*	0.39**
2. Mother affective vocal		–	0.68**	0.34**	0.41**	0.16	0.27*	0.35**
3. Mother affective facial			–	0.55**	0.39**	0.25*	0.44**	0.47**
4. Mother sensitivity/reciprocity				–	0.55**	0.31**	0.50**	0.61**
5. Infant attraction					–	0.38**	0.50**	0.85**
6. Infant affective vocal						–	0.45**	0.47**
7. Infant affective facial							–	0.54**
8. Infant sensitivity/reciprocity								–

df = 74 for all coefficients; *p < 0.05; **p < 0.01.

neutral expression while looking at the infant for two minutes ('maternal still-face', episode 2, E2); and resume playing with the infant for two minutes (episode 3, E3). If the infant cried, episode 2 was terminated early and the dyad moved into E3.

Infant behaviour during the still-face paradigm was coded in two passes using the Observer software. The per cent of the observed duration was calculated for infant gaze on/off mom, which was rated for duration. Rate per minute was calculated for infant smile, which was rated for frequency of occurrence (vs. duration). Per cent of the observed duration and rate per minute codes were converted to *z*-scores prior to composite derivation. Composite scores for *infant approach* were created for each episode of the still-face paradigm by summing the *z*-scores for infant smile rate per minute and the *z*-score of infant gaze on mom per cent of the observed duration, hence higher values indicate a higher proportion of time (in each episode) that the infant spent engaging in behaviours indicative of behavioural approach to mother. Inter-rater reliability was achieved for two independent coders, with intra-class *r*'s on rate per minute and per cent of the observed duration scores for each individual code across still-face paradigm episodes ranging from *r* = 0.81 to 0.99.

Infant physiological responding to the still-face paradigm

Infant electrocardiogram data were also acquired during the still-face paradigm. The electrocardiogram data were digitised at 1000 samples/second. R-waves were marked and cleaned with Mindware's editing software to remove artefacts due to equipment malfunction or movement. Mindware identifies possible artefacts based on height and temporal location of the QRS complex. The Mindware software was also used to compute beat-to-beat variability in RR-intervals that occur within the normal age-appropriate breathing frequency range, with bandwidth set at 0.3–1.3 Hz. This measure of high-frequency heart rate variability is taken as an estimate of Respiratory Sinus Arrhythmia, an index of vagal tone (26).

RESULTS

Attrition analyses

Of the 150 infants originally enrolled in the overall study, 103 returned for a 4-month follow-up visit (twin A in the

case of twins). A total of 76 mothers completed the face-to-face paradigm and were assessed on the WECS. Attrition analyses between those who remained in the study and those who dropped out at infant 4-month corrected age show no significant differences on study group, infant sex, twin status, birth order, gestational age at birth, maternal age or quality of maternal caregiving in-unit. There were also no significant differences between the 76 cases observed for the WECS and the 27 dyads who were seen at 4 months, but who did not engage in the 4-month face-to-face paradigm on the demographic variables or quality of maternal care in-unit. Dyads missing physiological data versus those with data did not differ on key demographic or observational variables.

Reliability of WECS coding

All WECS coding was completed by two independent coders who achieved good reliability on 17 cases of the sample, with agreement ranging from κ = 0.85 to 1.0 for maternal items and κ = 0.80 to 1.0 for infant items. Kappa was also computed for the binary (yes/no) Emotional Connection indicator on the same reliability sample, κ = 0.85.

WECS Internal consistency and data reduction

The four maternal WECS items were summed to create a *Mother WECS* (WECS-M) score, which represents the mother's engagement towards sustaining emotional connection with her infant. The four infant items were summed to create an *Infant WECS* (WECS-I) score, representing the infant's engagement towards sustaining emotional connection with the mother. Average Cronbach's α s were computed for: WECS-M scales (four items), α = 0.82; WECS-I scales (four items), α = 0.82; and all eight WECS items (mother and infant WECS items), α = 0.86. Table 3 presents the interrelations among the eight WECS items and delineates those items with significant interrelations. Mother and infant items most strongly correlated within each interactant's profile (average *r* for WECS-M items = 0.55; average *r* for WECS-I items = 0.53; average cross-interactant correlation = 0.37). WECS-M and WECS-I composite scores were significantly correlated, *r* (74) = 0.59, *p* < 0.001, but not redundant. Accordingly, WECS-M and WECS-I scores in all subsequent analyses were explored to assess the possibility of differential associations for WECS-M versus WECS-I, as each score represents the

interactant's display of emotionally connected behaviour towards the other and is plausibly differentially related to observed maternal and infant behaviour using other methodologies.

For the binary ratings of Emotional Connection using the WECS, 39 dyads were rated as connected (EC+) and 37 dyads were rated as not connected (EC-). The EC+ group had significantly higher WECS-M ($M = 11.32$, $SD = 0.94$) and WECS-I scores ($M = 9.54$, $SD = 1.74$) than EC- dyads ($M = 10.05$, $SD = 1.78$; $M = 7.34$, $SD = 1.53$, respectively), all p 's < 0.001 .

Association between pre-discharge maternal caregiving (36-week gestational age) and emotional connection at 4-month corrected age

We assessed the validity of WECS item ratings at 4-month corrected age by examining the associations between the WECS four dimensional scores and the quality of Maternal Caregiving Behaviour in the NICU prior to discharge (36-week gestational age) during diaper change, holding and feeding sessions while controlling for intervention status, twin status and gestational age at birth.¹ A series of regression analyses examined the separate dimensions of quality of maternal caregiving in-unit, including quality of touch, vocalisations and maternal sensitivity, averaged across holding, feeding and diapering episodes. Note that these dimensions are unilateral, mother to infant only and not reciprocal. WECS-M, but not WECS-I ($F < 1$) was significantly associated with *maternal sensitivity* and *quality of maternal vocal contact* averaged across the in-unit holding, feeding and diapering sessions: maternal sensitivity, $F(1, 63) = 4.83$, $r\Delta^2 = 0.24$, $p < 0.05$; quality of vocal contact, $F(1, 53) = 5.28$, $r\Delta = 0.28$, $p < 0.05$. No significant effect for quality of maternal touch was found.

Contemporaneous associations between emotional connection and behaviour coded using observational software

We assessed the contemporaneous associations between the WECS and maternal and infant social behaviour tracked with temporal precision in Noldus observational software, in the same period of 10-minute face-to-face play coded for the WECS. A series of multiple regressions examined associations between the WECS-M, and WECS-I and *maternal positive affect* and *infant positive social engagement*, controlling for intervention condition, twin status and gestational age at birth. The per cent duration of time mother spent in an affectively positive state was significantly associated with WECS-M, $F(1, 53) = 4.97$, $r\Delta = 0.26$, $p < 0.05$ and WECS-I, $F(1, 53) = 5.10$, $r\Delta = 0.28$, $p < 0.05$. WECS ratings were higher for both mother and infant when mothers were independently rated as spending more time in an affectively positive state using observational software. WECS-I scores

were also significantly associated with the proportion of time the infant spent positively socially engaged with mother, $F(1, 53) = 22.05$, $r\Delta = 0.52$, $p < 0.001$.

Emotional connection and infant biobehavioural responding

Our second aim was to test the hypothesis that a different pattern of behavioural and autonomic responding in the face of a relational stress could be detected among infants from dyads classified as EC+ versus EC-. First, three ANCOVA's were computed to examine differences in infant approach behaviour during the three episodes of the still-face paradigm while controlling for intervention status, twin status and gestational age at birth. A significant main effect for Emotional Connection group (EC+/-) on approach in E1 was found $F(1, 43) = 20.64$, $p < 0.01$, $\eta_p^2 = 0.21$. There was also a significant main effect for EC+/- group on approach at E3, $F(1,43) = 10.58$, $p < 0.01$, $\eta_p^2 = 0.25$. Hence, infants from EC+ dyads showed significantly more approach-seeking behaviour with mother before and after the still-face episode (E2). See Fig. 1.

To test the hypothesis that infants of EC+ dyads have healthier autonomic responses to the still-face paradigm stressor than infants of EC- dyads, two repeated measures ANCOVAs were computed, with changes in heart rate and respiratory sinus arrhythmia (vagal tone) as the dependent variables, respectively, and EC+/EC- (yes/no) as the between-subjects factor, with gestational age, intervention status and twin status, entered as covariates. Heart rate increased significantly from E1 (active interaction) to E2 (still face) across the sample (Fig. 1), and this was true for both EC- [$t(22) = -4.19$, $p < 0.01$] and EC+ [$t(26) = -4.96$, $p < 0.01$] infants. There was no significant group or group x still-face paradigm interaction effect.

A repeated measures ANCOVA was also computed to test for an association between dyadic Emotional Connection classification and change in infant respiratory sinus arrhythmia. Collapsed across Emotional Connection groups there was no significant change in respiratory sinus arrhythmia across still-face paradigm episodes. However, the changes in respiratory sinus arrhythmia across episodes were not the same for infants of EC- versus EC+ dyads: group x respiratory sinus arrhythmia change; $F(1, 39) = 6.24$, $p < 0.05$, $\eta_p^2 = 0.14$. In the EC- group, respiratory sinus arrhythmia *increased* significantly from E1 to E2, $p < 0.01$ with no further significant change from E2 to E3. In contrast, respiratory sinus arrhythmia decreased slightly, but not significantly, in the EC+ group across the three episodes of the still-face paradigm (see Fig. 1). Thus, EC+ and EC- infants in our sample exhibited different modes of autonomic responses to the still-face social stressor.

DISCUSSION

This study marks the first step in validating the construct of Emotional Connection, as well as an instrument for assessing Emotional Connection in mothers and their infants, the Welch Emotional Connection Screen (WECS). The WECS

¹Covariates used in all models reported in this paper do not significantly interact with WECS scores in predicting outcome measures.

²Denotes the incremental (semi-partial) correlation coefficient derived from the regression equation (controlling for covariates).

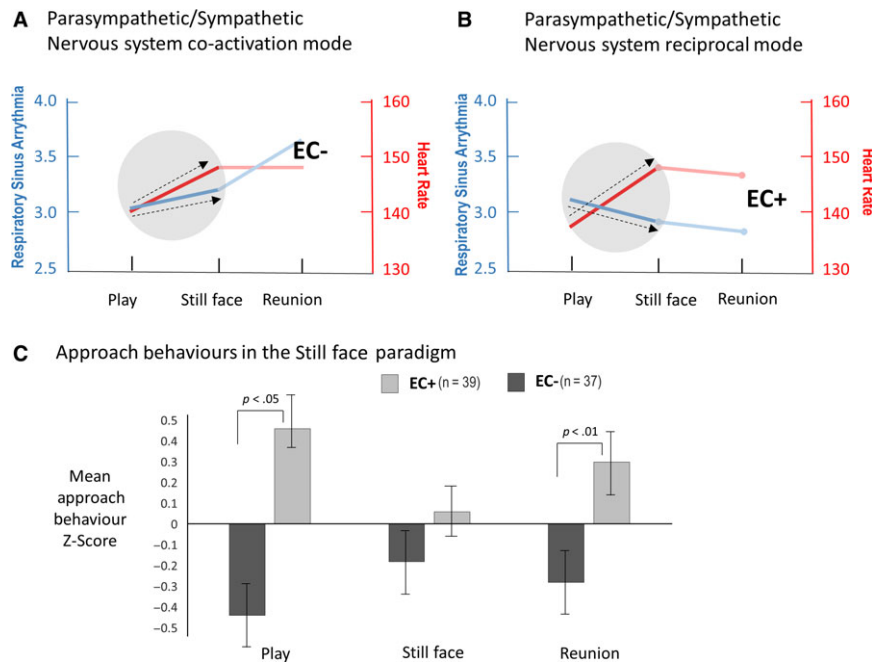


Figure 1 Infant Autonomic and Behavioural Differences in Still-Face Paradigm Responding for Emotionally Connected vs. Not Connected Dyads. Panel A shows the change in heart rate and respiratory sinus arrhythmia across the still-face paradigm for infants in dyads rated as not emotionally connected (EC-). Heart rate and respiratory sinus arrhythmia significantly increase from baseline to the still-face episode in this group, a profile consistent with co-activation of the parasympathetic and sympathetic branches of the autonomic nervous system. Panel B shows the change in heart rate and respiratory sinus arrhythmia for infants in dyads rated as emotionally connected (EC+). The increase in heart rate from baseline to the still-face episode is significant. Respiratory sinus arrhythmia decreases, though this suppression is not statistically significant. Panel C depicts the group mean differences in behavioural approach across the still-face paradigm based on EC +/- group. Relative to infants in EC- dyads, infants from EC+ dyads showed significantly more behavioural approach at the first and last episodes of the still-face paradigm.

is a brief observational tool that rates four behavioural dimensions that are indicators of Emotional Connection between mothers and preterm infants (Attraction, Vocal Communication, Facial Communication and Sensitivity/Reciprocity). These four dimensions are observed to inform a global determination of the dyad's mutual connection (yes/no).

We first tested the concurrent validity of the WECS dimensions by measuring associations between this brief screening tool rated during mother-preterm infant face-to-face interaction at infant 4-month corrected age, and other existing, more time-intensive, approaches to behavioural observation that quantify the behaviours measured by the WECS dimensions. This process included examining associations between coding of maternal vocal behaviour, touch and sensitivity during maternal caregiving at 36-week gestational age, while these preterm infants were still in the NICU, and the WECS rated at infant corrected age 4 months. We also compared the 4-month corrected age WECS coding of mother and infant behaviours with social behaviours (affect, gaze, vocalisations) quantified by observational software at the same age in the same face-to-face paradigm.

Our second aim was to assess the validity of the Emotional Connection construct, as measured by the WECS. The WECS observational paradigm is non-structured and devoid of toys or other objects, with the simple instruction to the

mother, 'interact with your infant'. The core of Emotional Connection is mutual comfort and ease in sustaining closeness via touch, gaze, voice and timing of responses to one another. We theorise that this closeness, when experienced repetitively, conditions healthy co-regulation of the dyad's autonomic nervous systems (16). To test construct validity, we examined whether dyads rated as EC+ on the WECS differed from those rated as EC- on biobehavioural responding of the infants during the still-face paradigm. We measured infant approach behaviour towards mother, heart rate and vagal tone both before and after the stress of the maternal still-face episode at 4-month corrected age.

Validating the WECS with other observational measures

We first sought to determine whether the coding of the four mother and infant domains, as well as the dichotomous coding of emotional connection (yes or no) was reliable across coders. After a short period of training, we found very good concordance among coders. We also examined internal consistency of the WECS and found that the dimensional scores had sound internal consistency. Hence, attraction, vocal communication, facial communication and sensitivity/reciprocity converge to measure the construct of emotional connection.

Next, we examined the associations of dimensions of the WECS with more labour-intensive, established coding

approaches. We examined the antecedents of Emotional Connection via associations of the WECS with observed maternal caregiving behaviour, while the infants were still in the NICU. More sensitive maternal caregiving and higher quality of vocal contact in-unit, prior to discharge, were significantly associated with higher ratings of maternal Emotional Connection at 4-month corrected age post-discharge. We did not find a significant association between WECS-M scores and quality of maternal touch. This may be due to the vastly different conditions under which mothers engaged in touch in the NICU, while the infant was tethered to medical equipment, versus the face-to-face exchange at 4-month corrected age, where there were no barriers to touching the infant. The results for maternal sensitivity and vocal contact offer validation of the WECS coding, as the in-unit coding was completed by a different team of coders who were blind to all other data. The data reported here reveal that more vocally stimulating mothers, and those who were sensitive to their infants' needs during routine in-unit caregiving tasks at 36-week gestational age were more likely to engage in the same behaviours once out of the hospital at the 4-month corrected age follow-up. Hence, working to improve the quality of Maternal Caregiving Behaviour prior to discharge may have important implications for ensuring Emotional Connection later in infancy.

We also examined the contemporaneous associations between the WECS and maternal and infant behaviour tracked using temporally precise techniques in the same 10-minute face-to-face play paradigm at 4-month corrected age. WECS ratings of Emotional Connection for mother and infant were associated with independent ratings of maternal positive affect. The proportion of time mothers spent manifesting positive affect during the 10-minute observation was significantly correlated with the global WECS-M score. Maternal positive affect may draw the infant into Emotional Connection, as WECS-I scores were also significantly associated with the proportion of time mothers manifested positive affect. This supports the dyadic nature of the WECS coding and the construct of Emotional Connection. The WECS-I scores were also significantly and robustly associated with the infant's social behaviour tracked by the observational software. Relative to infants rated as lower on the WECS, infants rated high on the WECS spent significantly more time gazing at and vocalising with their mothers in the same 10-minute observation. These findings support the contention that the coding approach used in the WECS is valid, as these are the same behaviours captured by the WECS quantified with temporal precision in the same observational window and by a different team of blinded coders.

Emotional connection and infant biobehavioural response to the still face paradigm

We investigated the construct validity of the WECS and tested the hypothesis that Emotional Connection is associated with differences in biobehavioural responding to relationship stress. To this end, we examined differences

in infant behavioural responding to the stress of the still-face paradigm, based on whether infants were from dyads rated as emotionally connected or not (EC+/EC-). Our hypothesis regarding behaviour was supported, as infants from EC+ dyads showed significantly more approach-seeking behaviour than those from EC- dyads, both before and after the stress of the maternal still-face episode. Hence, infants from connected, EC+ dyads were more open to looking to their mothers for social engagement at the start of the still-face paradigm and to resume this behaviour to reunite with their mother after the relationship disruption. Previous research shows that relative to full-terms infants, preterm infants are significantly more likely to become distressed faster and remain in a negative state longer in the still-face paradigm (27). The fact that EC+ infants looked to mother for social engagement suggests that Emotional Connection supports behavioural regulation in preterm infants.

These behavioural findings are consistent with the physiological data, which reveal important differences in infant autonomic response based on Emotional Connection status. In response to the still-face paradigm stress, EC- infants displayed increased heart rate and, paradoxically, increases in respiratory sinus arrhythmia. The significant increase in both respiratory sinus arrhythmia and heart rate in response to the stress of the maternal still face represents a non-reciprocal, co-activated autonomic response. This pattern of co-activation is associated with heightened vigilance and preparedness (28–30). Bernstein proposes that in the face of a stressor, co-activation of autonomic reactivity may occur when the individual is ambiguous as to the most advantageous behavioural response (31). Porges has suggested that co-activation may occur in the presence of a stressor because parasympathetic activation has lost regulatory influence over sympathetic activation (32).

Co-activation was not seen in EC+ infants, who showed increased heart rate and a non-significant trend for vagal suppression across the still-face episodes. It is understandable that both groups experience an increase in sympathetic activity following the stressful event. However, the co-activation mode of responding exhibited by EC- infants suggests they did not behaviourally engage, nor benefit physiologically from, the opportunity for social reengagement with their mothers. Instead, EC- infants were physiologically dysregulated, a condition that has been shown to be maladaptive in early infancy (33).

Autonomic co-activation (i.e. increases in heart rate and vagal tone) in infants of EC- dyads may be a maladaptive conditioned autonomic 'reflex' to the stressor of maternal withdrawal in the still-face paradigm (13,14). Accordingly, the conditioned autonomic response in infants of dyads coded EC-, results in both parasympathetic vagal tone and even greater sympathetic activity increases, leading to a net increase in heart rate. On the other hand, with dyads coded EC+, we expected to see an adaptive parasympathetic reflex to the still-face paradigm stress, i.e. decreased vagal tone, coupled with an increased sympathetic reaction, as indicated by increased heart rate. Although the change in

respiratory sinus arrhythmia across the still-face paradigm was not significant for EC+ infants, it is of note that EC+ infants showed a non-significant trend towards vagal suppression to the stress of the still-face paradigm. Additionally, EC+ infants were significantly more likely to seek re-engagement with mother after the stress of the still-face paradigm. Though speculative, it is plausible that preterm infants in EC+ dyads may continue to show more social engagement and healthier modes of autonomic responding across development. This may be particularly evident in the still-face paradigm if the reunion episode is extended (27). Thus, this is fruitful ground for future research.

While there are many tools that assess the quality of mother–infant interactions (34,35) none exclusively assesses the degree of mutual Emotional Connection between parent and infant. The Emotional Availability Scales are widely used to assess emotional availability through attachment theory-based psychological self-reports (36). While the term Emotional Connection is used in describing emotional availability, emotional availability refers to a dyad's 'capacity' for Emotional Connection, not whether there is mutual connection. These scales measure the extent to which Emotional Availability is positive and healthy, and the extent to which the dyad can separately and individually accommodate and regulate negative affect (37). The Emotional Availability Scales focus largely on indicators of social cognitive behaviours, such as the infant's responding and obedience to the parents' bids, and maternal psychological regulation of infant behaviour, such as structuring and other behaviours that the mother can change through teaching and education (38). The Emotional Availability Scales, to our knowledge, are thus far based solely on behavioural indicators and have not been related to physiological indicators (39).

In contrast, Emotional Connection as assessed by the WECS refers to the dyad's achievement of a mutual state of Emotional Connection, as opposed to individual capacity or availability to connect. The WECS does not employ self-reports, rather it relies on third-party observation of the dyad's interactions. Also, the WECS focuses on behaviours that we theorise reflect *autonomic states* of mother and infant. Thus, the Emotional Connection construct was validated by correlating behavioural data coded on the WECS with behavioural and physiological data simultaneously acquired during a relational stress paradigm.

Limitations and future directions

The data presented here focus on the WECS observed while mothers and infants interacted at 4-month corrected age. As well, while prediction from 36-week gestational age to 4-month corrected age was examined, the predictive validity of the WECS was not tested herein. Future analyses of data from the physiological profiles in EC+ versus EC– dyads earlier than 4 months of age, and longitudinally at later ages, are necessary to elucidate the role of Emotional Connection in the development of preterm infants and the physiological co-regulation hypothesis. Such research in other groups of infants is also necessary to determine whether EC+/EC– is associated with a host of suboptimal

mother–infant interactions that place infants at developmental risk, including maternal depression (40) and other types of early adversity (41). While there is much potential for the WECS to be used in research with community samples of mothers and infants for basic research or as a screening tool for at-risk mother–infant dyads, the findings reported here are based on mothers and preterm infants, which limits generalisability.

The data presented here are WECS ratings derived from 10-minute video-taped observations filmed in a research laboratory. This marks a necessary step in validating the development of the WECS dimensional ratings and the EC+/- differences in autonomic responding. However, the WECS was designed with an eye towards feasibility for use in clinical settings. Additional research is underway to validate the WECS with live, in-clinic coding. We have further developed the WECS by merging the separate mother–infant codes to rating the mutual indicators of EC on the four WECS dimensions and accommodating live coding in clinical settings with much shorter observations. The results of this initial development and validation study, coupled with the efficiency of training and use of this screening tool, suggest that this is a promising future direction. Arming clinicians with a tool that can be feasibly used to identify at-risk dyads may have significant implications for the course of treatments to follow. It is our hope that such treatments would focus on working to support mothers and their preterm infants in establishing and maintaining an emotional connection prior to discharge from the hospital, as doing so may assist mothers and their infants in experiencing a more mutually rewarding relationship, and may well serve to promote healthier biobehavioural regulation.

SUMMARY

Taken together, the results of the present study demonstrate that the WECS is a valid instrument for assessing Emotional Connection in preterm mother–infant dyads. The WECS showed sound psychometric properties; was associated with maternal care behaviour earlier in development (prior to discharge as 36-week gestational age); and was associated with observed behaviour measured contemporaneously, tracked with temporal precision in observational software. Taken together, these findings support the validity of our global screening approach. As well, Emotional Connection as measured by the WECS, was associated with physiological responding to stress in preterm infants. Hence, these data provide support for the theoretical foundation of the WECS, suggesting that Emotional Connection is a behavioural mirror of the dyad's co-regulatory autonomic response to contact with one another.

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