THE IMPACT OF MALNUTRITION ON CAMBODIAN INFANTS' SOCIAL LEARNING AND RELATIONSHIP WITH THEIR MOTHER

by

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Malnutrition in infants and children in early stages of life is a serious problem in third world countries around the globe. Undernutrition contributes to delays in cognitive development, language acquisition, and physical growth. The current research project focuses on the possibility that infant malnutrition, and in particular, thiamine deficiency, may negatively impact infants' ability to respond to maternal efforts to engage with them socially. The focal point of my research involved validating a task -- the Primary Engagement Task (PET) -- designed to measure caregiver-infant positive mutual engagement. I observed 2-week-old infants' responses in this task as mothers used multiple modalities to engage with infants; specifically, I coded how infants' state changed over the course of the task. Of particular interest was the degree to which infant state changes corresponded to mothers' use of additional tools to elicit positive engagement. I found that as mothers increased their deployment of visual, auditory, and tactile behaviors, infants progressively become more alert; similarly, infants' state declined in alertness as maternal cues to engagement were progressively withdrawn. These findings provided initial validation for the PET as a technique that elicits systematic state changes in infants, thereby setting the stage for use of this measure to investigate individual differences -- such as differences in malnutrition history and thiamine status -- in infants' responding on this task.

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Literature Review

Malnutrition is a critically destabilizing issue in third world countries. Researchers have found that more than half of malnourished children live in Asia and one-third in Africa (UNICEF, WHO & World Bank Group, 2016). Malnourished infants are at high risk of infant mortality. According to the World Health Organization, undernutrition is the cause of 70% of neonatal deaths and a factor in over 50% of infants who die after the first month of life (“Malnutrition,” 2018). Causes of deficiencies include poor quality of food, inadequate amount of food, decreased nutrient absorption, and intestinal infections. These infections are often caused by unsanitary environments. A particular form of malnutrition -- thiamine deficiency (also called beriberi) -- is common in Laos, Cambodia, and Myanmar. Thiamine deficiency arises in part as a result of the typical diet of Southeast Asian populations, as polished rice has virtually no thiamine and is a key component of their diet (Coats et al., 2012). Thiamine deficiency contributes significantly to infant mortality in Cambodia. If infants do not receive rapid attention for this deficiency, they are at risk of death within their first few months of life (Barennes, Sengkhamyong, René & Phimmasane, 2015).

In addition to undercutting the likelihood of infant survival, malnutrition also has documented effects on the growth, health, and cognitive and socio-emotional outcomes of infants who survive. The severity of the impact of malnutrition on cognitive and developmental deficits has been studied in various populations. Ample nutrition for an infant during pregnancy and the first three years of life is essential to the infant’s brain development and social learning (Prado & Dewey, 2014). This critical period of an infant’s early life determines the long-term effects of nourishment or malnourishment. (Ghosh et al., 2015). There is a large body of evidence indicating that early prenatal malnutrition leads to negative effects on brain development. In particular, malnutrition has been found to directly impact brain development and can result in functional and structural deficits along with learning impairments (Kar, Rao & Chandramouli, 2008). These researchers found that children who were malnourished performed poorly on cognitive tests regarding attention, learning and memory, and working memory. As well, thiamine deficiency, in particular, has been shown to have negative consequences for children's brain development and cognitive outcomes, such as delays in language development, auditory comprehension, and expressive communication (Fattal-Valevski et al., 2009). It is worth noting that impairments resulting from malnutrition may also have long-lasting effects on children's relationships with others. Malnutrition may undercut social functioning by virtue of its impact on neural development and cognitive development.

Interestingly, research on attempts to ameliorate malnutrition via nutrient supplementation appears to reveal that supplements alone are only minimally effective in reducing malnutrition; in contrast, nutritional supplements combined with interventions that promote supportive parenting tend to be more effective in improving children's developmental outcomes (Grantham-McGregor et al., 2014). In a randomized controlled trial, Grantham-McGregor and colleagues found that malnourished children in Jamaica who received nutritional supplementation as well as nurturing stimulation from their mother displayed developmental outcomes (e.g., learning, hearing and speech development) closest to a control group of non-stunted children (Figure 1). The combination of parental care and nutritional supplementation seems to best promote outcomes that are close to those of non-stunted, healthy children. These findings help clarify that malnutrition manifests as more than a simple nutritional deficit; ameliorating the effects of malnutrition thus seems to require interventions that go beyond nutritional supplementation alone. Given these finding, it is somewhat surprising that relatively little research directly investigates the impact of malnutrition on the quality of caregiver-infant interaction.

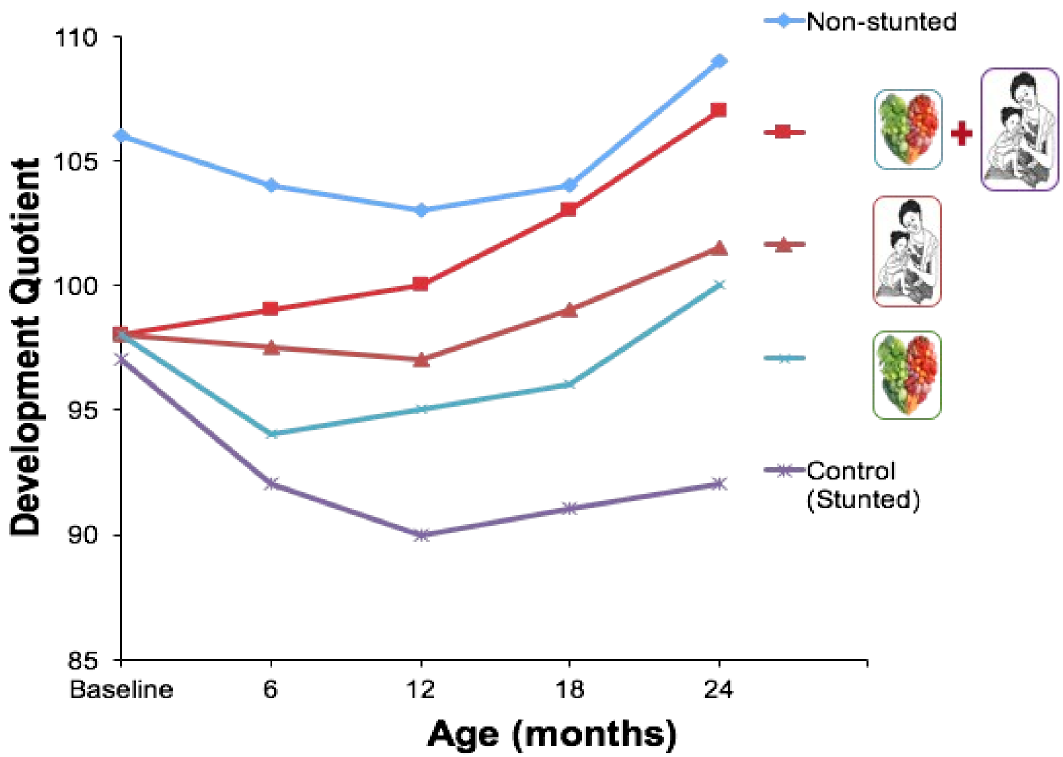

Figure 1: Effects of Malnutrition, Nutritional Supplements & Mother Nourishment

A large body of research indicates that responsive and sensitive care from a mother is crucial for meeting infants' needs and thus, for positive developmental outcomes ("Responsive Caregiving," 2019). Responsive care is when a mother is attentive to the infant's cues, readily reads and appropriately interprets what they might mean, and then responds in a sensitive way. Responsive and sensitive care of this kind from a primary caregiver early in the infant's life promotes secure attachment, which in turn is immensely beneficial to the infant's development ("Responsive Caregiving," 2019). Interestingly, there is a care "sweet spot" for each individual infant in which stimulation is carefully balanced with respect to what a particular baby needs and prefers. Too much stimulation will cause the infant to retract and be less engaged and too little stimulation will not fulfill the infant's needs (Walker, Chang, Powell & Grantham-McGregor, 2005). This mutual engagement and communication allows the caregiver and the infant to feel secure in their relationship.

There are many challenges caregivers face in providing responsive and sensitive care, especially in regions that are economically depressed such as Southeast Asia. Mothers may lack knowledge or appropriate models of responsive and sensitive care, and thus are unable to provide it for their infants. War and political upheaval in the mid-20th century in places such as Southeast Asia, and more specifically Cambodia, led to widespread societal breakdown in cultural transmission of parenting traditions, possibly undercutting both the acquisition of knowledge about responsive and sensitive care and the social support needed for caregivers to be able to provide high quality care for infants ("Cambodian Genocide Program," 2019). In countries where malnutrition rates are high, mothers themselves face disadvantages. A lack of resources, a lack of social support, and mental health challenges such as anxiety and depression may directly challenge their ability to provide the care that infants need. We thus hypothesize that malnutrition, and thiamine deficiency included, may undercut both mothers' and infants' ability to engage in emotionally fulfilling, responsive and sensitive interactions.

One overarching goal of the research of which my thesis is a part of is to investigate a subset of this hypothesis. In particular, this project investigates the degree to which infant malnutrition, including thiamine deficiency, may undercut infants' ability to respond effectively to caregivers' efforts to connect with them in a responsive and sensitive manner. This investigation is itself embedded within a larger study investigating the developmental implications of malnutrition, and thiamine deficiency in particular, on Cambodian infants' development. An international group of researchers led by Kyly Whitfield of Mount Saint Vincent University conducted a randomized controlled trial in Cambodia of varying levels of thiamine supplementation for mothers who were exclusively breastfeeding (and thus their infant's sole source of thiamine). They assayed mother and infants' blood for indices of nutritional status as well as thiamine status, and also measured infants' neurobehavioral health, growth, emotional well-being, and quality of dyadic interaction at 2 weeks, 3 months, and 6 months (Whitfield et al., 2019). Dr. Dare Baldwin at the University of Oregon is a collaborator on this large-scale longitudinal study. The specific part of this larger project that my thesis focuses on concerns validating the efficacy of a new method for assessing infants' responsiveness to caregivers' efforts to connect with them. My thesis research involves a subset of data that was collected as part of this large-scale investigative effort.

One component of participation in Whitfield et al.'s longitudinal study involved caregivers being asked to take part in a "primary engagement task" (PET). The task is designed to provide an opportunity to observe caregivers as they attempt to establish a mutually positive interaction with their infant and to observe how successful they are in eliciting a positive response from their infant. The overarching goal of the PET is for caregivers to try to coax a smile from their infant and sustain positive engagement with the infant over the course of the task. However, caregivers are asked to go about this in a somewhat scripted manner. This task follows a stepping up and then stepping down pattern separated into six epochs or phases. Within each epoch, the caregiver is to follow specific instructions. During epoch 1, the caregiver cradles the baby but turns her head away, avoiding eye contact. For epoch 2, the caregiver turns her face to the infant and only attempts to elicit a smile through facial expressions. During epoch 3, the caregiver adds voice. During epoch 4, the caregiver adds touch. Then, for epoch 5, the caregiver proceeds to step back down and eliminates touch yet still uses her voice. Finally, for epoch 6, the caregiver eliminates voice and returns back to solely using facial expressions.

To measure infant state changes in relation to caregivers' efforts to establish positive mutual engagement, we utilized a system for coding infant state changes developed by Tronick (2004) and included as part of the Network Neurobehavioral Scale (NNNS) that is a standard measure used by clinicians to assess infant neurological status. Empirical evidence confirms that the NNNS is a valid measure of infant neurological functioning (Tronick & Lester, 2013). The 6-state scale, in particular, involves rating infants as in a state of quiet sleep, active sleep, drowsy, quiet awake, active awake, or crying. We used this infant state measurement as a diagnostic of infants' responsiveness to the caregiver in the context of the PET. We hypothesized that infants who are malnourished, or thiamine deficient, may be relatively unresponsive to the caregiver's efforts to engage with them. We predicted that malnourished or thiamine-deficient infants will show reduced levels of state change in response to the caregiver's attempts to coax and sustain positive engagement over the course of the PET. A first step toward testing these predictions involved validating our particular method for coding changes in infant state as a useful index of infants' responding during the PET. Testing for such validation was the specific focus of my thesis. My hypothesis was that infants will show increased levels of alertness and activity as mothers increased their efforts to engage with the infants. This would validate state coding as a measure of infants' response to caregivers in the PET, which in turn would suggest that infant state in the PET is potentially suitable for investigating individual differences in infants' ability to participate in positive mutual interaction with their caregiver.

To undertake this validation effort, I was trained on the infant state coding system, and then used the system to code state changes in 39 infants over the course of the PET at the 2-week-old measurement time-point. If the state-coding system appropriately indexes infant state changes in the PET, infants overall should display either a linear or quadratic trend in their state changes across the PET. That is, as the PET progresses during the stepping up phase, infants' state should increase from baseline, and then either be sustained at a higher level, or decline during the course of the stepping down phase of the task.

Method

Participants

Videos of 44 mother-infant dyads were included in the research. Infants were two weeks old at the time the videos were recorded. Of the 44 videos, 5 videos were omitted from analysis due to either poor lighting at night or researcher error, leaving 39 videos retained for analysis. Mother-infant dyads all lived in Kampong Thom district in Cambodia and consented to participate in the larger randomized-control trial investigating the benefits of thiamine supplementation for infant well-being.

Procedure

All mother-infant pairs participated in the PET. This task measures the ease with which mother-infant dyads can maintain a positive social connection over the course of the task. It offers the opportunity to measure both how effectively mothers can establish and sustain infants' attention and interest, as well as how responsive infants are to their caregiver. My thesis research focused specifically on measuring infant state changes over the course of the task.

The PET involved six epochs where mothers were given specific instructions regarding how to behave with her infant at 30-second intervals. Mothers were given overall instructions that the goal of the task was to try to coax a smile from her baby and sustain it over the course of the task. In addition, the task was divided into 30-second intervals, with the first several intervals involving stepping up new ways to elicit positive engagement (e.g., facial expression, plus voice, plus touch) with infants, and the final two 30-second intervals involving progressively stepping down these methods (e.g., removing touch, then removing voice). Mothers were given overall instructions before the task began. As well, the researcher provided specific prompts at the beginning of each 30-second interval to help cue mothers regarding the specific instructions for that epoch.

The task began with the mother cradling the 2-week old infant as she was given instructions every 30 seconds. The mother could also choose to place the baby on a pillow on the ground and shift her body so that she and the baby were face to face. The first 30 seconds, epoch 1, a baseline phase, involved the mother completely looking away. Next, in epoch 2, the mother was told to look at the baby in an attempt to elicit a response solely by means of her facial expressions. Next, for epoch 3, the mother's voice was added and she could talk to her infant however she pleased. Then, for epoch 4, touch was added where the mother touched the baby with her hands. In epoch 5, touch was removed leaving just face and voice. Lastly, epoch 6 included just facial expression, bringing the epochs full circle.

Researchers administering instructions were highly trained, native Khmer speakers (the native language of Cambodia).

Coding

A first coding pass of the videotapes involved identifying the onset of each of the six epochs of the PET. With this accomplished, a second pass through the videotapes focused on coding changes in infant state across the six epochs. Codes for infant state were: 1 – quiet sleep; 2 – active sleep; 3 – drowsy; 4 – quiet awake; 5 – active awake; and 6 – crying. Each state has a specific, detailed description in order to effectively select the best state per epoch (Appendix A).

An aspect of the videos that quickly emerged as coding began was that some mothers continuously rocked their babies throughout different epochs. Since epoch 4 is when touch was added, as long as mothers changed the way they touched their baby, the rocking was acceptable and did not alter the data collection. For example, if a mother was patting her baby until she reached epoch 4, when she touched her baby's arm instead, this was said to be acceptable for following the instructions of the epoch.

For purposes of establishing the reliability of the state coding system, an additional coder is currently in the midst of independently re-coding at least 10 of the same mother-infant pairs experiencing the PET when infants were 2 weeks old. This coding is as yet incomplete; thus a reliability estimate for the infant state coding is not yet available. However, it is important to note that the state coding system was borrowed directly from the NNNS (as described earlier) and in that context, infant state coding was meticulously validated as a sensitive and reliable measure of infant neurobehavioral health (Tronick & Lester, 2013).

Results

In order to validate state coding as a useful index of infants' responses to caregivers in the PET, a first step involved a descriptive examination of the state codes. Of particular interest was whether the state coding produced data with range, variability, and normality to be amenable for the goal of using the state coding system to investigate individual differences in mother-infant behavior in the PET in the future with the full dataset. Infant state codes displayed considerable range and means varied across the six different epochs, as seen in Table 1. On average, babies' state codes tended to increase as the mother's stimulating behaviors increased, and then decreased during epochs 5 and 6, as the mothers stepped down with respect to the cues they were using to engage with infants (see Appendix B). We examined the distributions of infants' state separately within each epoch; none of these distributions departed from normality. Thus we were subsequently able to use parametric techniques, such as analysis of variance, to examine changes in infant state across the six epochs of the PET.

Epoch	Mean	SD
1 Baseline	3.82	1.048
2 Face	4.03	1.038
3 Face + Voice	4.36	0.903
4 Face + Voice + Touch	4.51	0.914
5 Face + Voice	4.37	1.074
6 Face	4.18	1.254

Table 1: Infant State Means and Standard Deviations Across Epochs

Figure 2 presents all the data regarding infants' state changes across the six epochs of the PET. It is noteworthy from examination of the data in Figure 2 that infants' mean state was highest during epoch 4 of the PET, which was, in fact, the high point of the PET in terms of mothers' inclusion of the maximum number of modalities for interacting with infants (facial expression plus voice plus touch). Figure 2 also clearly reveals obvious variability in babies' states across epochs. On inspection, this variability seems to have been to some degree anchored by infants' starting state in the first, baseline, epoch, in which mothers were not yet interacting with infants. In our subsequent analyses, we examine the extent to which these observations emerge as statistically systematic patterns in the data.

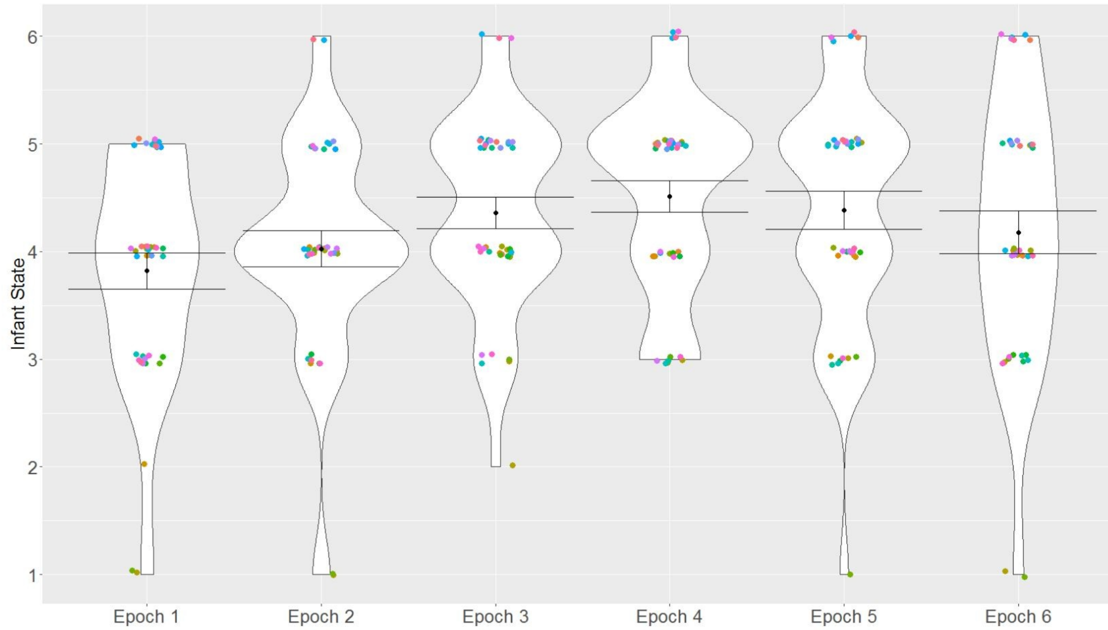

Figure 2: 39 Individual Infants' Changes in State Across the Six Epochs

To examine the influence of infants' baseline state on state changes over the course of the PET, we conducted an analysis of variance across the six epochs. Our question of central interest was whether infants' state would display systematic change across the six epochs of the PET. The repeated measures, one-way ANOVA which tested changes in infant state across the six epochs revealed a significant main effect of epoch, $F(5,190)=8.47$, $p=0.000$, partial ETA^2=0.18. This indicated that infants' state displayed systematic differences across epochs, confirming that the state coding indeed captures measurable change in infants' state across the PET. Moreover, polynomial contrasts testing for the pattern of infant state changes across epochs revealed both a significant linear trend, $F(1,38)=10.75$, $p=0.002$, partial ETA^2=0.221, and a significant quadratic trend, $F(1,38)=15.29$, $p=0.000$, partial ETA^2=0.287. These changes in infant state in relation to the mother's changing behaviors across the PET are clearly apparent in Figure 2.

We conducted a follow-up analysis in which we treated infants' state in the first epoch as a measure of their baseline starting state and treated it as a covariate in an analysis of covariance examining state changes across the subsequent five epochs. This repeated-measures ANCOVA also revealed a significant main effect of epoch (Greenhouse-Geisser $F(3.14, 116.04) = 5.42$, $p = .001$). However, polynomial contrasts on the epoch variable in this ANCOVA revealed that the linear trend was no longer significant ($F(1, 37) = .19$, $p = .67$), but the quadratic trend for state across epochs maintained statistical significance ($F(1, 37) = 13.80$, $p = .001$). This finding indicated that, even when controlling for infants' baseline starting state, infants' state tended to systematically increase as mothers progressively added modalities (e.g., facial expression, voice, touch) to their interactions with infants during the PET, and then decrease as mothers progressively removed these modalities as the PET came to a conclusion. This demonstrates that the state change coding is sensitive to state changes across the epochs even when variance due to the infant starting state is controlled for.

Secondarily, we checked whether infants' state codes were intercorrelated. A test of intra-class correlation revealed a Cronbach's alpha of .94, indicating that infants' states across epochs were highly intercorrelated.

As part of our descriptive analyses, we conducted separate boxplots of infant state for each of the six epochs of the PET. These boxplots revealed that two infants displayed outlying state data-points over the course of the PET. In particular, these two infants were coded as in a deep sleep state at some point during the course of the task, whereas most infants were in states higher towards alertness on the state scale. We opted to redo the analyses described above with state data from these two infants eliminated, in order to examine the robustness of the findings. With these infants' state data removed, the linear and quadratic patterns in state changes were still present and statistically significant in the ANOVA. However, in the ANCOVA (controlling for epoch 1 as the baseline state), the within-subjects effect was lost, Greenhouse-Geisser $F(3.04,106.45)=1.42$, $p=0.23$, partial ETA^2=0.04, along with the linear trend, $F(1, 35)=.05$, $p=0.82$, partial ETA^2=0.002, and the quadratic trend was only marginally systematic, $F(1, 36)=3.04$, $p=0.09$, partial ETA^2=0.08. These findings seem to suggest that infant state changes for the majority of infants tended to be relatively restricted in range toward the top end of the state scale; this compression was especially pronounced when the two infants with outlying state scores were eliminated. As a result of the reduced variability, systematic state changes became more difficult to detect.

Discussion

My specific research aim was to discover whether 2-week old infants displayed systematic state changes in response to their caregiver's efforts to engage with them positively during the Primary Engagement Task. The question of interest of the larger study, of which this thesis comprised only a small part, was whether infant malnutrition or thiamine deficiency in particular, impacts infants' ability to effectively interact and engage with their caregiver. More generally, thiamine deficiency may undercut Cambodian babies' developmental thriving, including hindering babies from developing responsive interactions with their mothers. This might be demonstrated by reduced or sluggish responses to mothers' attempts at mutual engagement. For example, when mothers produce facial, vocal, or touch cues indicating a desire to engage, infants might fail or be slow to become alert to such cues, fail or be slow to provide eye contact, and/or fail or be slow to turn in the mother's direction. The Primary Engagement Task (PET) was developed to test these predictions. It involved mothers introducing a graduated series of cues indicating a desire for mutual engagement, followed by progressive removal of such cues. We predicted that babies would become progressively more alert and responsive to mothers as new engagement cues were introduced, and perhaps display reduced alertness as cues were removed. However, infants who are malnourished or thiamine deficient might have difficulty responding appropriately to mothers' interaction attempts and thus display significant differences in their state responses over the course of the PET. A first step in testing these predictions was to ensure that the coding scheme we developed for the PET was effective at picking up on infant state changes within the PET videos. If so, on average the mother's facial expressions, voice, and touch should act as a stimulus eliciting state increases, and the removal of such cues should be accompanied by state reductions. The results from videos of 39 mother-infant dyads participating in the PET supported our predictions that the babies' state codes would increase as the mother continued to interact with her baby, and decrease as she removed modalities (e.g., touch and voice) from her interaction efforts.

These findings indicate that the PET elicits systematic state changes in infants as mothers proceed through the stepping up, and stepping down structure of the task. This in turn offers at least initial promise that the PET will provide information about individual differences between mother-infant dyads in their ability to initiate and maintain mutual engagement, a necessary prerequisite for being able to test whether infant malnutrition and in particular, thiamine deficiency, affects such dyadic abilities for mutual engagement. Both the linear and quadratic trends validate the PET and confirm that it is working as it is supposed to in measuring infant state changes. The linear trend suggests that infants are responding to mothers' cues and once they become more alert, they sustain this alertness and maintain a positive increase. The quadratic trend demonstrates how infants become more alert with the mothers' engagement and then step back down when the mother removes her cues in the latter part of the task. This thesis research demonstrates that babies in the 2-week-old sub-sample became increasingly alert as the mother used her multiple modalities of interactions to engage her infant, which establishes the groundwork supporting the use of the PET to examine malnutrition-related individual differences within the context of the larger study goals.

As might be expected, infants' changes in state during the PET were anchored to some degree by their starting state, as measured by the first, baseline, epoch, in which mothers weren't yet interacting with babies. Our analyses revealed that infants' baseline state significantly predicted their average state across subsequent epochs. Critically, however, the quadratic pattern of state changes observed from epochs two through 6 of the PET remained systematic even when controlling for infants' baseline state during epoch one.

Although the present sub-sample was too small to undertake an investigation of individual differences, it is worth noting that anecdotally, some differences did seem to emerge. Certain mothers used their voice or touch in a way that seemed almost aggressive towards their infants which led to an abrupt change in infant state code. These mothers raised their voice or used their touch in a rough manner, resulting in their infant reaching state code 6, crying. This brings me back to the overarching goals of the larger study. Our hypothesis is that infant malnutrition may undercut infants' ability to respond to maternal bids for mutual engagement. However, malnutrition may also play a role in mothers' sensitivity (or lack thereof) towards their infants. Mothers may react in a less sensitive way towards infants who are malnourished. This larger implication brings to light how malnutrition might undercut mother-infant mutual engagement through multiple pathways.

To pursue these problematic interactions further, I was surprised to observe how certain mothers were insensitive towards their babies during epochs in which voice and touch were added, even when the babies responded poorly. When the babies began to cry, I expected mothers to reduce the intensity at which they attempted to connect with babies. Rather than being less rough and adjusting to a more sensitive interaction style, the mothers continued to overstimulate the babies. Note, however, that this expectation may well be due to pre-existent cultural bias on my part.

Another factor that may have impacted the nature of mutual engagement between mother and baby in the PET resides in possible cultural trends governing what is typical of mother-infant interaction in Cambodia. In particular, informal observation suggests that Cambodian mothers do not tend to speak to infants as young as 2 weeks of age, and typically may not try to initiate mutual engagement through any channel. Spontaneously talking to infants this young does not seem to be a common behavior within Cambodian culture. The instructions for epoch 3 of the PET involves the mother speaking to her baby, which quite possibly places Cambodian mothers out of their comfort zone. I noticed that mothers sometimes did not know what to say and it was difficult for them to attempt to capture the babies' attention with their voice. On the other hand, certain babies seemed to be quite responsiveness to their mothers' efforts to engage them; for example, they held long-lasting eye contact when the mother increased her engagement. This display of a mutually engaged pair seems to bode well for infants' developmental thriving. Given that the PET appears to effectively elicit such interactions, it will now be possible to discover whether malnutrition influences the likelihood that mother-infant dyads can achieve such positive mutual engagement.

The research provides strong validation that the state coding system is picking up on systematic variance, suggesting that it is a well-suited coding scheme for measuring quality of interactions between caregiver and infant. Once condition assignment has been unblinded, we will be informed of which infants are malnourished and which are healthy, allowing us to further analyze how infants' condition impacts their relationship with their mother.

Limitations

Several limitations made the results less broadly applicable than we might hope. Our sample size of 39 videos was small. Although the findings were clear with this small sample, a larger sample of coded videos would broaden our results. Another limitation was that the research lacked a formal reliability check to ensure that the video coding was consistent. Also, we only coded videos of 2-week olds and thus do not have the data for 3-month-olds and then 6-month-olds coded yet. Another limitation is that the state coding system was global and perhaps not the most sensitive possible way of measuring infants' responses to maternal behaviors in the PET. This global coding system also does not take into account how effective the mother is at engaging with her infant.

Future Directions

The formal reliability check regarding the video coding is underway along with coding videos of the 3-month-olds and 6-month-olds. In order to ascertain the baby's state, we will make sure the babies are well-rested and well-fed prior to the PE Test. This will rule out alternative factors that might affect the infants' change of state throughout the PE Test. Other, more time intensive, coding systems are underway hat provide detailed information about infant responses and caregiver behavior. Since the current coding system does not take into account how effective the mother is being in engaging with her baby, we will also code the effectiveness of the caregiver's signaling.

In the future, we will make sure the infants are well rested and well fed prior to participating in the PET. As some infants were held and some were laying on their backs on a cushion on the ground, we will also test to see whether this makes a difference.

Conclusion

I conclude that I have validated the PET. The overarching research concerns the extent to which malnutrition may alter infants' brain development, which we hypothesize, in turn, influences infants' ability to engage mutually with their mother. I found that as the epochs of the PET progressed, infants demonstrated significant changes in their states. These findings make possible the use of the PET to examine the extent to which malnutrition, and thiamine deficiency in particular, may impact the quality of infants' early social interactions with their mothers and the extent to which thiamine supplements protect the quality of infants' social engagement opportunities. As is amply apparent from the data and observations, a combination of close motherly attention and nutritional assistance may drastically improve the social and intellectual outlook for infants in Cambodia.

Appendix A: Infant State Codes

Code	Description
1	**Quiet Sleep (State 1):** Sleep with regular breathing, eyes closed, no spontaneous activity except startles or jerky movements at quite regular intervals; external stimuli produce startles with some delay; suppression of startles is rapid; state changes are less likely than from other states; and no eye movements.
2	**Active Sleep (State 2):** Sleep with eyes closed; rapid eye movements often can be observed under closed lids; low activity level, with random movements and startles or startle equivalents; movements are likely to be smoother and more monitored than in State 1; responds to internal and external stimuli with startle equivalents, often with a resulting change of state. Respiration is irregular; sucking movements occur on and off. Eye opening may occur briefly at intervals.
3	**Drowsy (State 3):** Eyes may be open but dull and heavy lidded, or closed, eyelids fluttering; activity level minimal, may be reactive to sensory stimuli, but response often delayed. Movements are usually smooth though there may be startles. Infant has a dazed appearance and is minimally reactive even when his or her eyes are open. This is also considered a "transitional" state and is sometimes difficult to score. Some infants may also show fuss/cry vocalizations in this state. When this happens, State 3 may be difficult to distinguish from State 5. The minimal movement in State 3 and considerable movement in State 5 is what distinguishes State 3 from State 5 when both are accompanied by fuss/cry vocalizations.
4	**Quiet Awake (State 4):** Alert, eyes open with bright look and appropriate changes in facial expression as stimulation is varied; focuses attention on source of stimulation, or a visual or auditory stimulus. Motor activity is minimal. There can be a glazed look that is easily changed into a brighter look with appropriate stimulation.
5	**Active Awake (State 5):** Eyes likely to be open, considerable motor activity, with thrusting movements of the extremities, and even a few spontaneous startles; reactive to external stimulation with increase in startles or motor activity, but discrete reactions difficult to distinguish because of general activity level. Brief fussy vocalizations can occur in this state. Some infants may transition directly from lower states (1, 2, or 3) directly to State 5. These often are the cases described above in which fuss/cry vocalizations occur at States 5 and 3 are difficult to distinguish unless the difference in motor activity is taken into account.

6 **Crying (State 6):** Characterized by intense, loud, rhythmic, and sustained cry vocalizations, which are difficult to break through with stimulation; motor activity is high. It is important to distinguish between cry as a state from fuss/cry vocalizations that can occur in State 5 and even State 3. Some infants have shown repeated episodes of fuss/cry vocalization in State 5 but may not reach State 6. This may also be a maturational issue, as some preterm infants may not have the energy reserves to sustain State 6. In general, State 6 can be distinguished from State 5 by the intensity and sustained quality of the crying (at least 15 seconds) and unavailability of the infant in State 6. Repeated brief episodes of fuss/cry in State 5 do not mean that the infant has moved into State 6. Coders need to give the infant the opportunity to show State 6. Premature administration of consolability and cuddling maneuvers may prevent the infant from reaching State 6 and provide an inaccurate assessment of the infant.

Appendix B: Observed Infant State per Epoch

	EPOCH					
Video	**Epoch 1**	**Epoch 2**	**Epoch 3**	**Epoch 4**	**Epoch 5**	**Epoch 6**
A001	4	5	5	5	4	5
A002	5	4	4	5	5.5	6
A003	4	4	4	4	4	4
A004	4	4	4	4	4	4
A005	4	4	4	4	4	4
B008	2	3	3	5	3	3
B009	4	4	4	5	5	5
B010	1	1	2	3	3	1
B011	4	4	4	5	5	4
B012	4	4	4	4	4	4
B013	1	1	3	3	1	1
B014	3	4	4	3	3	3
C001	3	3	4	4	4	3
C002	3	3	4	4	3	3
C003	4	4	5	5	4	3
C004	5	5	5	5	5	5
C012	5	5	5	5	5	5
D001	3	4	4	3	3	3
D002	4	4	5	5	5	5
D004	3	3	3	3	3	3
D010	5	5	5	5	5	6
D012	4	4	4	5	5	4
D014	5	5	5	6	6	4
E001	5	6	6	6	6	6
E002	4	4	5	4	5	5
E004	5	5	5	5	5	5
E005	4	4	5	5	5	4
E016	5	5	5	5	5	5
E018	5	5	5	5	5	5
F001	3	4	5	5	4	4
F002	3	4	3	3	5	6
F007	4	4	4	4	4	4
G002	5	5	6	6	6	6
G012	3	4	4	4	4	3

H001	3	3	3	3	3	3
H003	4	4	4	5	5	4
H005	4	4	5	5	4	4
H011	3	3	6	6	6	6
H012	5	6	5	5	5	5

Table 1 (Appendix B): Observed Infant State per Epoch

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