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Hemoglobin, Growth, and Attention of Infants in Southern Ethiopia

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Abstract

Researchers tested male and female infants from rural Ethiopia to investigate relations among hemoglobin, anthropometry, and attention. They utilized a longitudinal design to examine differences in attention performance from 6 ($M = 24.9$ weeks, $n = 89$) to 9 months of age ($M = 40.6$ weeks, $n = 85$), differences hypothesized to be related to changes in iron status and growth delays. Stunting (length-for-age z -scores < -2.0) and attention performance [$t(30) = -2.42$, $p = .022$] worsened over time. Growth and hemoglobin predicted attention at 9 months [$R^2 = .15$, $p < .05$], but not at 6. The use of the attention task at 9 months was supported. The study contributes to the knowledge base of hemoglobin, growth, and attention.

Keywords

Development; Cognitive; Attention; Growth; Hemoglobin

Hemoglobin, Growth, and Attention of Infants in Southern Ethiopia

A significant body of literature has demonstrated a clear link between nutritional status and indicators of cognitive development (Black, 2003a; Kar, Rao, & Chandramouli, 2008; Pravosudov, Lavenex, & Omanska, 2005). These relations have been particularly well-documented with regard to micronutrient deficiencies such as iron (see Grantham-McGregor

& Ani, 2001, and Thomas, Grant, & Aubuchon-Endsley, 2009, for reviews). Given the notable relations between attention and cognitive outcomes (Choudhury & Gorman, 2000; Domsch, Lohaus, & Thomas, 2009; Kannass & Oakes, 2008), early measures of attention have been increasingly used as indicators of cognitive development and associated with nutritional variables (Kannass, Colombo, & Carlson, 2009). In fact, numerous recent investigations have found robust associations between nutrition and attention (Burden et al., 2007; Kannass et al., 2009; Kennedy et al., 2008). Moreover, many of these studies have been carried out in underdeveloped countries, given the increased risk of nutritional deficiencies within these populations (see Grantham-McGregor et al., 2007, and Walker et al., 2007, for reviews). The present study specifically investigated the relations among hemoglobin (an indicator of iron status), anthropometric growth measures (indicators of infant health and general nutritional status), and attention during infancy. The study sampled a rural population in southern Ethiopia, a country that has a high incidence of iron deficiency/anemia (World Health Organization, 2006) and malnutrition (World Health Organization, 2007) in children.

Nutrition

Measures of growth and specific vitamin and mineral status in children under 5 years of age have been used as general indicators of health by both researchers (Bhutta et al., 2008; Black et al., 2008; Victora et al., 2008) and policy makers (United Nations Children's Fund, 2009). Hemoglobin concentration, used in the present study, has been recommended as an indicator for iron deficiency anemia by the World Health Organization (United Nations Children's Fund, United Nations University, & World Health Organization, 2001), while growth status has been measured by weight, length, and head circumference and has been associated with energy and protein nutrition (de Onis, Garza, Onyango, & Martorell, 2006; World Health Organization, 1986, 1995) as well as specific nutrients such as zinc (International Zinc Nutrition Consultative Group, 2009). The interpretability of these growth measures has been enhanced by comparing an individual child's/infant's measurements to a standard population, leading to the creation of an age-specific z-score (de Onis et al., 2006). For infants, weight was most affected by recent energy balance, while length was affected by longer term protein energy intake and micronutrient status, particularly zinc (Abebe, 2008; International Zinc Nutrition Consultative Group, 2009; World Health Organization 1986). In general, head circumference has been less sensitive to nutritional factors, so there is reason to believe that variance in explaining cognitive/attention functioning via this variable may be unique or independent from the other two anthropometric variables.

Iron—There have been several reviews investigating the negative effects of iron deficiency on early cognitive development (Grantham-McGregor, 2003; Grantham-McGregor & Ani, 2001; Thomas et al., 2009). Early iron status has also been shown to be significantly related to cognitive performance in later childhood and adolescence (Halterman, Kaczorowski, Szilagyi, Aligne, & Auinger, 2001; Lozoff, Jimenez, Hagen, Mollen, & Wolf, 2000). These studies have even demonstrated the robust effect of iron deficiency on cognitive performance after controlling for possible confounds such as maternal education (Hubbs-Tait, Kennedy, & Droke, 2007). Such effects have been demonstrated in numerous samples (e.g., infants from Chile, Costa Rica, Israel, France, and the United States) with varying sociodemographic and cultural characteristics (Grantham-McGregor & Ani, 2001), further attesting to the robust relation between iron deficiency and cognitive development. In addition to these established relations, more preliminary studies have documented the direct relations between iron deficiency/status and attentional development, including attention span deficits both within and across age (Hulthén, 2003; Lozoff, 1989; Walter, Kovalskys, & Stekel, 1983).

Furthermore, Burden et al. (2007) used event-related potentials (ERPs) of anemic and non-anemic infants at 9 and/or 12 months of age as a measure of the infants' abilities to discriminate faces. They found that the mid-latency negative component was more prominent in the iron-sufficient group at 9 months, indicating more attentional resources being allocated to the infants' mothers' faces. This response was congruent with the age appropriate pattern, whereas the smaller amplitude shown by the anemic infants was not.

Growth—In addition to iron status/deficiency, growth measures have also been strongly associated with cognition and preliminarily associated with attention in infancy. Regarding the former, Skuse, Pickles, Wolke, and Reilly (1994) have used the timing, duration and severity of growth faltering to predict mental functioning in 15-month-old infants. Another study by Rose (1994) found significant relations between two cognitive measures of information processing and weight and length in 183 5- to 12-month-old infants. Several more recent studies (Fernald et al., 2006; Ketema, Abate, & Jabar, 2003; Lima et al., 2004) investigated infants of low socioeconomic status and found similar results. Specifically, Fernald and colleagues (2006) found significant relations between height-for-age and age-adjusted scores on the Bayley Mental Development Index (MDI; Bayley, 1993) in a sample of Mexican infants (12.5–23.5 months old). Lima et al. (2004) found that weight-for-age and length-for-age were related to the MDI in 12-month-old infants in a low income population from northeastern Brazil. Ketema and colleagues (2003) found similar associations between length-for-age and cognitive performance in a sample of infants from central Ethiopia.

Only one study was found that investigated the relations between growth and attention within infancy. Specifically, a study by Kennedy et al. (2008) found significant differences in performance on the single stimulus/novelty preference task between 6- to 8-month-old infants with poor anthropometric indicators and their normative peers: Infants with z-scores of -2 or less on either weight-for-age or length-for-age displayed significantly longer looks at stimuli and slower mean shift rates during familiarization.

Infant Attention

Prediction of later outcomes—Shorter looking time early in infancy has been associated with greater intellectual functioning later in childhood, from toddlerhood to adolescence (see Kavšek, 2004, for a meta-analysis). These relations have been demonstrated across numerous attentional paradigms (e.g., habituation, dishabituation, and visual expectation; Domsch et al., 2009). These relations have also been demonstrated using several measures of later intellectual functioning (e.g., the Bayley Scales of Infant Development-II [BSID-II; Bayley, 1993] Mental Development Index [MDI] and the Kaufman Assessment Battery for Children [K-ABC; Kaufman & Kaufman, 1983]).

Later in infancy and into toddlerhood, longer looking has predicted better intellectual functioning. For instance, several studies have utilized infants 8 months or older and demonstrated that performance on sustained attention tasks during later infancy was significantly related to MDI scores on the BSID-II within (Choudhury & Gorman, 2000) and across (Kopp & Vaughn, 1982) age, up to 2 years old. Kopp and Vaughn (1982) also found a significant relation between sustained attention in 8-month-olds and performance on the Gesell Development Schedules. In addition, Kannass and Oakes (2008) found significant relations between 9-month-olds' performance on the multiple object free play (MOFP) task and performance on the Peabody Picture Vocabulary Test-Revised (PPVT-R) at 31 months of age.

Attentional development and endogenous attention—Early infancy attention measures have been typically single-object, non-competitive tasks, whereas later infancy

measures tend to be competitive tasks that focus on sustaining attention in the face of distraction (Ruff & Rothbart, 1996). Regarding the former, an infant's longest look has been used as a measure of encoding speed. However, looking time has tended to decrease over the first 6 months of life, but increase after this age (Colombo & Cheatham, 2006). A common theory used to explain these developmental changes in infants' looking behavior has been that of endogenous attention.

Colombo and Cheatham (2006) defined the development of endogenous attention as "the process through which the allocation of attention is controlled by stimuli, objects, or events that are internal to the organism" (p. 589). Exogenous attention, seen in younger infants, has been characterized by the combination of knowledge gathering and perceptual aspects that take place early in life when the process of learning about and interacting with the world is based on externally driven factors (Gibson, 1988). Conversely, endogenous attention has been defined as self-directed or inhibited by the individual. Colombo and Cheatham have explained the decrease in look duration that occurs from 3 to 6 months of age as reflecting improvements in the speed of encoding visual stimuli. As endogenous attention develops, infants are able to internally regulate and focus their attention, thus longer look durations are thought to reflect a greater ability to sustain or maintain attention on a particular object, while filtering out others (Colombo, 2001).

The paradigm used within the current study, the MOFP task, included giving the infant several toys with which he or she might play without interrupting him/her during play. Variables coded within this paradigm included shifts in attention from toy to toy or mean duration of looking at the toys. In these competitive tasks, looking duration at any object has increased from approximately 6 to 7 months of age to early toddlerhood and the number of shifts in visual attention among objects has decreased, which was in contrast to the pattern of findings within non-competitive tasks. Colombo, Kannass, and their colleagues (2004) have used the MOFP paradigm to study relations between attention and nutritional variables. Kannass et al. (2009) found that greater maternal docosahexaenoic acid (DHA) at birth was related to longer look durations and fewer periods of inattention on the MOFP task at 18 months of age. Similar results were reported by Colombo et al. (2004) in both single object free play and distractibility tasks. This suggests that the free play paradigm was a measure of attention with sufficient sensitivity to capture the influences of nutritional variables.

Although Ruff and Rothbart (1996) suggested that the relation between age and look duration was linear within free play tasks, Kannass and colleagues (2006) conducted a study demonstrating a discontinuous relation between attention performance, as measured by look duration, from early infancy to late infancy/toddlerhood. Specifically, Kannass et al. (2006) used both the MOFP and distractibility tasks and found there were significant longitudinal relations between earlier (7 to 9 months of age) and later (9 and 31 months of age) attention variables, but that there were no significant direct relations between infants' attention performance at 7 and 31 months of age. The researchers postulated that this may be due to underlying developmental changes in endogenous control of attention and may raise issues about the appropriateness of such tasks for assessing attention in young infants, who do not have such abilities. This again supported the theory of endogenous attention development and the use of the MOFP task to capture the developmental change from exogenous to endogenous control of attention.

Summary

A rich body of literature exists that defines a robust relation between nutrition in infancy and cognitive development. The role of iron has been particularly well-established. However, most of these studies have utilized general measures of cognitive function; there are few that

have focused on attention. The same can be said for general measures of growth as well. The relations between such measures and attention have not been well-established.

Furthermore, attention develops dramatically over the first year of life. In the latter half of the first year, sustained, or endogenous, attention becomes increasingly under the control of the infant. There is currently a paucity of research that has examined the relation of nutritional variables to endogenous attention, which supports the relevance of the present study.

Present Study

The current study investigated how hemoglobin concentrations and standardized anthropometric measurements at 6 and 9 months of age are related to endogenous attention assessed using a MOFP task. A sample of infants from southern Ethiopia was used in order to extend the research focus to a cross-cultural context and investigate a sample with known nutritional deficiencies (Abebe et al., 2008).

Based on the extant literature, we hypothesized that nutritional and growth variables would significantly predict attention engagement in Ethiopian infants in the latter part of their first year of life. Specifically we predicted that (1) there would be no statistically significant relations between growth/iron status and attention variables at 6 months of age because (a) endogenous control of attention is minimal at this age, and (b) growth/iron status tends to negatively impact task performance later in infancy. We further hypothesized that (2) these relations should emerge in the 9-month-old infants, such that nutritional indicators (weight-for-age z-score [WAZ], length-for-age z-score [LAZ], head-circumference-for-age z-score [HCZ], and infant hemoglobin concentration [Hb]) would significantly predict several variables indicative of sustained attention, including: total duration of looking, shifts in attention, mean looking time, total duration of inattention, number of inattention periods, and mean inattention time. Furthermore, (3) an exploratory analysis of the relations between 6-month nutrition/growth variables and 9-month attention performance was also conducted.

Method

Participants

A convenience sample of 108 infants (49 boys and 59 girls) and their mothers were recruited from four different villages in the Sidama region of southern Ethiopia. Participants were part of a larger longitudinal study with testing at 6 and 9 months of age. Researchers collaborated with community health workers who informed mothers about the nature of the study and recruited them to participate. Participation was voluntary and all protocols were approved by the institutional review boards of Oklahoma State University and Hawassa University (Awassa, Ethiopia). Each mother was audio recorded giving oral consent for the study and a picture was taken of her baby to ensure the same baby was brought back for the second phase of the study. Mothers were compensated for participation at the 6-month visit with a t-shirt for the infant, a bottle of hair oil, and a photograph of mother and baby. At the 9-month visit, the mothers received another photograph and a shawl.

The sample was extremely homogeneous with regard to demographics. Of the initial 108 infants, the occupation of the heads-of-household from which those infants came was self-employed farming in 105 (97%) cases. Ten of these heads-of-household also had non-farming jobs but only three were employed in non-agricultural positions. Ninety-two mothers (85%) had 4 or fewer years of schooling. Similarly, dietary diversity was also very limited. Even at 9 months, all infants were nursing with 65% receiving a single type of complementary food (Berhanu et al., 2010). Because of this extreme homogeneity, demographic and dietary factors were not used in statistical analyses.

In terms of health statistics, no information about the micronutrient status or rate of parasitic infection was taken from mothers. However, according to the World Health Organization (WHO; 2006), 26.6% of Ethiopian women within reproductive age (15–49.99 years) are anemic (i.e., Hb < 11.5g/dL, adjusted for altitude). Additionally, malaria is thought to affect almost 75% of Ethiopia with an estimated 50 million people (60%) at risk for the development of this parasitic infection (Central Statistical Agency [Ethiopia] and ORC Macro, 2006). Approximately 10% of pregnant women within the country are treated for parasitic infections. Within our sample, 43% of families reported using bed nets to prevent malaria. However, only four infants tested positive for malaria and because they appeared healthy, their data were used in the analyses. This number is likely to have been low because the Sidama region is at a relatively high altitude (1700m above sea level) and the infants had not yet endured the wet season, in which malaria exposure is most prevalent. For the current study, no information about infant supplementation, or other forms of treatment, was taken. However, infants that were ill were excluded from the study and infants that were anemic were referred to the Bushelo Health Clinic for treatment. All infants within the current sample were breastfeeding through 9 months, suggesting that their health and nutritional status were dependent on their mothers. However, virtually all (96%) received supplementary foods by 9-months of age, though regional food lacks important micronutrient content such as zinc and iodine (Abebe et al., 2008).

According to the Ethiopia Demographic and Health Survey (EDHS; Central Statistical Agency [Ethiopia] & ORC Macro, 2006) approximately 94% of infants are born at home: 6% are delivered with the help of a trained professional (doctor, nurse, or midwife), 28% by a traditional birth attendant, 61% are attended by a relative or other person, and 5% are not assisted at all. Thus, birth weights are estimated to be measured only 3% of the time. Of these, 14% are less than 2.5kg at birth. Within rural areas, 23% of newborns are estimated to weigh less than 2.5kg. Maternal self-report measures suggest that 21% of births result in very small infants and 7% of mothers reported that their infants were smaller than average. Results of the EDHS suggest that over 70% of mothers receive no antenatal care. For the current sample's region (Southern Nations, Nationalities, and People's Region), antenatal care is thought to be somewhat better than the national average, which is partially due to the presence of the Bushelo Health Clinic that provides immunizations and pregnancy tracking within the area.

As suggested previously, only infants who appeared to be healthy and were reported as being so by their mothers were asked to participate. Of 108 infants who met these criteria, 89 had usable video data for the purposes of the present study. Nineteen 6-month-old infants were excluded due to experimenter error (4) and technical problems (1), or the procedure had to be stopped because the infant became upset during testing (8), was ill (1), or was unable to sit up by him/herself (3). Two infants were also excluded because they were determined to have been born preterm. Infants' ages were documented by immunization records that mothers brought with them. At the 6-month testing, the mean age of the 89 infants was 24.9 weeks (range = 21.4–30.0 weeks). At the 9-month testing, 97 infants returned (46 boys, 51 girls), with 85 infants providing usable data, although anthropometric data were not collected from one female. Data from 12 of the infants at 9 months were not used due to experimenter error (4) and technical problems (3), or the procedure had to be stopped because the infant became upset during testing (5). These 85 infants ranged in age from 39.3 to 42.1 weeks with a mean of 40.6 weeks.

Given the difference in age range across age groups (8.6 weeks for 6-month-olds and 3.2 weeks for 9-month-olds), an investigation of outliers was performed for variables that could be affected by these differences (i.e., Hb and attention variables that are not corrected for age like the anthropometric variables) in the 6-month-old sample. These analyses revealed

that there were several extreme and suspected outliers in this sample, so analyses presented below, that were conducted *across* age utilized a 6-month-old sample that was trimmed to have the same age range as the 9-month-old sample. This was thought to be sufficient given that there was no overlap in age between the two samples. See the Results section below for an elaboration.

Materials

A general demographic questionnaire was verbally administered to assess the mothers' socioeconomic status (SES) and their children's feeding habits. This assessed mothers' education level and the occupation of the head-of-household. Due to the regional norms, the SES assessment also requested information such as the type of roof the family's house was made of and the distance traveled to retrieve water. Information about breastfeeding, vaccinations, and use of bed nets for the babies was also collected for other aspects of the larger study.

A drop of blood was taken from infants to measure hemoglobin (Hb) concentrations. A trained and experienced laboratory technician was hired to take blood samples. The Hb test was done in the field using HemoCue® (Ängelholm, Sweden). Capillary blood from the infant's heel was drawn into a microcuvette containing the reagent by capillary action. The microcuvette was then inserted into a portable photometer and results were displayed and recorded. Infant weight, length, and head circumference were measured by assistants trained in anthropometric assessment by senior research staff, who were regularly re-evaluated for consistent adherence to protocol. Arm circumference was also measured, but not used in this study. Weight was taken using a United Nations Children's Fund (UNICEF) mother-infant solar-powered platform scale by Seca, which was regularly calibrated. The length of the infants was assessed using portable length measuring boards, accuracy $\pm .2\text{cm}$ (Shorr Productions, Olney, MD) with the measuring tape inlaid into the body of the board to assure reliable measurements. Head circumference was assessed using a UNICEF tape measure. Length and circumference measurements were taken three times, and the mean was then calculated for use. WHO child growth standards software converted the anthropometric measurements to z-scores.

Procedure

A modified version of the Laboratory Temperament Assessment Battery (Lab-TAB; Grant, 2009), developed originally by Goldsmith and Rothbart (1988), was used to collect temperament data. This laboratory procedure was designed to assess early temperament in a controlled and objective setting, emulating situations that infants would typically encounter. Ten of the original Lab-TAB episodes were used following cultural modifications: two joy/pleasure, two fearfulness, two interest/persistence, two anger/frustration, and two activity level. Each episode was 3–5 minutes in length and designed to elicit temperament behaviors such as emotional expressivity, approach/avoidance, activity level, and self-regulation.

The current study utilized one of the Lab-TAB episodes for assessing infant attention. This episode was a MOFP task that was originally designed for Lab-TAB to measure infants' activity levels. Researchers recoded this episode from the Lab-TAB videotapes originally collected using a scoring protocol developed by Kannass and colleagues (Kannass et al., 2006; Kannass et al., 2009; Kannass & Oakes, 2008) in order to assess attention. During this episode, infants were individually seated on the ground and presented with a box of six small toys for 3 minutes. Each box of toys consisted of some combination of six of the following: a Ronald McDonald action figure, a stuffed bird with a rattle, a stuffed soccer ball, a stuffed football, oversized plastic keys on a key ring, and an assortment of plastic rattles. The mother was instructed to support the child's trunk, if necessary. In all but three

cases at 6 months of age, infants could sit unsupported without the help of their mothers to support their trunks. Both the parent and the experimenter kept their interactions to a minimum. All sessions were recorded using a Panasonic camcorder and videos were coded within the nearest second.

Coding

Upon first viewing the chosen videos, for purposes of the present study, researchers used a stopwatch to calculate the total time (to the nearest second) an infant looked at any toy (including the box in which the toys were placed) during the 3-min episode, allowing the stopwatch to run, accruing time during looking times, and stopping it during looks away from the toys. During a second viewing, researchers tallied the number of shifts in attention displayed by an infant. A shift in attention was defined as a look that was 0.5s or longer in duration directed at anything or any toy other than the toy at which the infant was previously looking. Looks to the same toy that were separated by a short look (i.e., less than 0.5s) were combined. Although total looking time was rounded to the nearest second, the stopwatches recorded time to the hundredth of a second, making the distinction between less than and greater than 0.5s possible. For purposes of inter-rater reliability, an additional coder reassessed 13 of the videos of 6-month-old infants and 24 of the videos of 9-month-old infants. Using intraclass correlations, with the 6-month-olds' videos, inter-rater reliability ranged from .80 to .91, with a mean of .88. With the 9-month videos, inter-rater reliability ranged from .85 to .99, with a mean of .91.

Six indicators of attention/inattention were computed: (1) total number of looks to the toys or "shifts in attention," (2) total duration of looking (looking at the toys), (3) the mean length of individual looks to the toys, (4) total number of episodes of inattention, (5) the total duration of inattention, and (6) the mean length of inattention periods. These variables were used to describe infants' tendencies/abilities to maintain attention to a particular stimulus in a competitive context. For example, during MOFP tasks, an infant may be distracted by the numerous toys that he/she may choose from and therefore have a lesser mean looking (attentive) time or more shifts in attention across objects.

Results

Anthropometry and Hemoglobin

Descriptive statistics were computed for the anthropometric and hemoglobin data at both 6 and 9 months (see Table 1). An infant was considered to have low Hb if the concentration was less than 11.5 g/dL (United Nations Children's Fund et al., 2001). This Hb criterion was adjusted for the altitude based on the following formula (Nestel, 2002):

$$\text{Hb} = -0.32 \times (\text{altitude in meters} \times .0033) + 0.22 \times (\text{altitude in meters} \times .003)^2$$

This adjustment was needed because the altitude of the Sidama zone is 1700m above sea level. At 6 months, 35 infants (34%) were classified as having low Hb and at 9 months, 34 infants (36%) were classified as such. Seventeen of the infants with low Hb at 6 months were still classified with low Hb at 9 months. The mean values of all three anthropometric measures decreased from 6 to 9 months (Table 1), most notably length-for-age z-score (LAZ). At 6 months, the mean LAZ was -1.03 (range = -3.88 to $+2.15$); LAZ decreased to a mean of -1.62 at 9 months (range = -4.82 to $+1.25$). Sixteen infants (15%) were moderately stunted at 6 months (i.e., $-3.0 < \text{LAZ} < -2.0$) and ten infants (9%) were severely stunted at 6 months (i.e., had $\text{LAZ} < -3.0$). These number increased to 19 (20%) and 15

(16%) respectively, at 9 months. Twenty-three of the infants classified as stunted at 6 months were still stunted at 9 months.

Additional analyses were run separately at each age to examine possible differences in anthropometric data and hemoglobin between infants with usable attention data and those without. At 6 months of age, the 19 infants who did not have usable data were of significantly smaller length-for-age (LAZ; $M = -1.68$, $SD = 1.30$) than those with usable data ($M = -0.90$, $SD = 1.32$, $t(104) = -2.29$, $p = .024$). No other significant differences were found within anthropometric measures and hemoglobin concentrations at 6 months. At 9 months of age, no significant differences were found in anthropometry or hemoglobin between infants who provided attention data and those who did not ($n = 12$).

Attention

Paired-sample *t*-tests were run to compare the six attention variables across age (from 6 to 9 months). Given that these analyses were performed across age and there was a large difference in the age ranges between the 6- and 9-month samples, the 6-month sample was trimmed so that the age range for this sample was the same as the 9-month data (i.e., 20 days or a range from 163–183 days old; $M = 175.31$ days, $SD = 5.9$ days, $n = 52$). After adjustment, there were no age differences in total duration of looking, $t(30) = -0.52$, $p = .61$; number of attention shifts, $t(30) = 1.77$, $p = .09$; total inattention time, $t(30) = 0.78$, $p = .44$; number of inattention periods, $t(30) = 0.40$, $p = .69$; or mean inattention time, $t(30) = -0.10$, $p = .93$. However, at 9 months of age, infants had significantly lower mean looking times, $t(30) = -2.42$, $p = .022$.

Six Month Attention

Correlations—Descriptive statistics on the 6-month attention data (see Table 1) and a correlation matrix were used to examine possible relations among the 6-month variables (see Table 2). Negative correlations were found between LAZ and both total inattention time, $r = -.21$, $p = .046$, and mean inattention time, $r = -.26$, $p = .017$. No other significant relations were found.

Regression analyses—Separate multiple regression analyses were conducted using all four nutritional measures as predictors of each of the six attention measures. Given the large and statistically significant intercorrelations among the three anthropometric measures within age (range at 6 months was $r = .21$ to $r = .64$, all $ps < .05$; range at 9 months was $r = .26$ to $r = .61$, all $ps < .01$), multicollinearity statistics were performed to support the use of these individual predictors within regression equations. No evidence of multicollinearity was found as all tolerance values were above 0.60, and several regression equations were conducted using these measures as predictors. None of the correlations between hemoglobin and the three anthropometric variables within age were statistically significant, thus multicollinearity diagnostics were not performed and hemoglobin was used as an additional predictor with the three anthropometric variables to predict each of the attention measures. None of these regression analyses were statistically significant at 6 months of age.

Nine Month Attention

Correlations—For the 9-month data, a correlation matrix was used to examine relations among variables (see Table 3). A positive correlation was found between mean looking time and Hb, $r = .23$, $p = .037$. No other significant correlations were found.

Regression analyses—Separate multiple regression analyses were conducted using all four nutritional measures as predictors for each of the six attention measures. Significant variance was accounted for in two of these models: mean looking time and number of

attention shifts. A standard multiple regression analysis was used to determine which of the four 9-month predictor variables (Hemoglobin [Hb], weight-for-age z-score [WAZ], length-for-age z-score [LAZ], and head-circumference-for-age z-score [HCZ]) predicted mean looking time (see Table 4). The regression analysis indicated that the overall model significantly predicted mean looking time, $F(4, 77) = 3.40, p = .013$. This model accounted for 15% of the variance in attention performance at 9 months of age. A summary of regression coefficients is presented in Table 4 and indicates that both Hb and HCZ significantly contributed to the model, such that higher concentrations of Hb and larger HCZ were associated with longer mean looks when infants were 9 months of age.

A standard multiple regression analysis was also used to determine which of the four predictor variables (Hb, WAZ, LAZ, and HCZ) predicted the number of attention shifts when infants were 9 months of age (see Table 4). Results indicated that the overall model significantly predicted attention shifts, $R^2 = .15, F(4, 77) = 3.44, p = .012$. Similar to that found with mean looking time at 9 months, Hb and HCZ again both significantly contributed to the model (see Table 4). Here, however, Hb and HCZ both negatively predicted number of attention shifts at 9 months, such that higher concentrations of Hb and larger HCZ were associated with fewer shifts in attention when infants were 9 months of age. WAZ approached significance in its contribution to the model ($p = .058$) with a positive correlation.

Six to Nine Month Relations

Of the original 108 participants, 38 infants did not have usable data at either 6 or 9 months of age, resulting in a sample size of 70. After trimming the 6-month sample to match the age range of the 9-month sample, there were 46 infants left, with which correlations were calculated to examine relations between 6-month nutritional variables and 9-month attention measures. No significant correlations were found.

Discussion

Changes in Health and Attention over Time

Infants showed a greater degree of stunting over time (from 6 to 9 months of age). Namely, the mean LAZ decreased from -1.03 to -1.62 and the percentage of infants below -2.0 increased from 25% to 36%. WAZ and HCZ also declined, but Hb was stable. These declines are not surprising given the nutritional deficiencies noted within this region that affect both mothers and infants (World Health Organization, 2007). Breast milk alone becomes an inadequate source of nutrition after about 6 months of age (Krebs, 2000) and staple foods in the region are low in several micronutrients (e.g., zinc and iodine) and protein (Abebe et al., 2008). Attention performance also significantly worsened over time (i.e., mean looking time), in contrast to normative developmental trends (Kannass et al., 2006).

Hypothesis 1: 6 Month Relations

The first hypothesis was partially supported in that the nutritional variables at 6 months of age could not significantly predict any of the three attention variables that directly tapped attention, namely total looking time, mean looking time, and number of shifts. As stated previously, this may be due to a lack of endogenous control at this age (Kannass et al., 2006). Infants' performance on the task may not be mediated internally and thus would not be expected to be significantly related to nutritional indicators, which impact cognitive abilities. Infants at this age also have much less control over their motor functions, especially infants that are malnourished (Aburto, Ramirez-Zea, Neufeld, & Flores-Ayala, 2009; Shafira, Angulo-Barrosob, Suc, Jacobs, & Lozoff, 2009). Thus, orienting behavior

and shifts in gaze behavior may have been difficult for these infants to control. This further supports the contention that the MOFP task may be inappropriate to use with infants this young (Kannass et al., 2006). In addition, the influence of poor nutritional status on neurocognitive correlates may not emerge until later infancy. In fact, the only other known study to use the MOFP task in this context found significant relations between nutrition and attention with older infants (i.e., 12 and 18-month-old; Kannass et al., 2009).

Contrary to the first hypothesis, there were statistically significant relations between nutrition and the three measures of inattention at 6 months of age. Infants that had lower LAZ were more inattentive (total and mean inattention time). Perhaps this is because of the severity of nutritional deficiency within the 6 month sample. Nutritional deficiency is thought to partially mediate the differences in significant relations seen across age and there were several infants (9%) that were severely stunted within the 6 month sample. This means that the relation between nutrition and inattention at 6 months of age may have emerged since the degree of stunting was so notable, especially in comparison to the other anthropometric variables at 6 months of age (i.e., WAZ, 2% severely and 8% moderately underweight; HCZ, 0 small; LAZ, 15% moderately and 9% severely stunted). Consistent with this idea, these findings may be partially mediated by the impact of other forms of development, as suggested above. Specifically, there have been numerous studies documenting the relations between motoric/behavioral development and nutrition (e.g., Black, 2003a; Black et al., 2004; Grantham-McGregor, Fernald, & Sethuraman, 1999a; Grantham-McGregor, Fernald, & Sethuraman 1999b). Therefore, perhaps those with poorer nutrition are not able to physically orient to particular stimuli, which compounded their difficulties sustaining attention.

In sum, the results of the regression analyses support the first hypothesis, despite the fact that there were two statistically significant correlations between LAZ and inattention at 6 months. It is notable that LAZ was the most severely impacted of all anthropometric variables and this may be related to a nutritional variable not assessed in the current study. For instance, a previous study utilizing a similar sample (Abebe et al., 2008) demonstrated marked zinc deficiencies, which are related to stunting (International Zinc Nutrition Consultative Group, 2009; Umata et al., 2000). The findings support the claim that the later development of endogenous attention may make the MOFP task inappropriate for younger infants. Future studies could investigate this hypothesis by having a larger sample of infants. The sample could be divided into those with and without clinically significant nutritional impairments at different ages and then after being matched on important variables, differences in attention performance could be investigated.

Hypothesis 2: 9 Month Relations

The second hypothesis was also supported in that there was a positive correlation between mean looking time and hemoglobin concentration within the 9-month-old sample. The combination of standardized nutritional variables (Hb, WAZ, LAZ, and HCZ) significantly predicted mean looking time and number of attention shifts, two measures that showed *declines* in attention capacity from 6 to 9 months. The two statistically significant predictors to these relations, Hb and HCZ were positively related to mean looking time and negatively related to shifts in attention, indicating that greater hemoglobin concentrations and head circumferences were associated with a greater ability to sustain attention. There is no clear reason why certain attention and nutritional variables were significantly related. One implication of the findings is that Hb and HCZ may be more closely related to attention performance or that attention measures may be more sensitive to these nutrition/growth variables. For instance, both variables that were significant were variables of attention rather than inattention. Perhaps low iron affects some attention variables more than others, due to its neurological impact.

Overall, these findings further support both the theory of endogenous attention and the relation between nutrition and attention. Findings suggest that the MOFP task and associated variables are valid ways of measuring attention at 9 months of age, given the previously documented theoretical and practical overlap between nutritional and attentional variables. The combination of findings from hypotheses 1 and 2 suggests that these relations may be most appropriately investigated in older infants. This may be due to the appearance of endogenous control of attention or because this is when nutritional deficiencies are marked enough to have a significant effect on cognition, perhaps because the protective effects of breastfeeding are beginning to decline and adequate complementary feeding practices are not employed (Shrimpton et al., 2001).

Future studies could investigate the sensitivity and specificity of different indicators of nutritional status (i.e., aside from iron status) for predicting later attention performance. Given that previous studies have noted the differential impact of various micronutrients on neural maturation and cognitive functioning (e.g., see Black, 2003b, for a review of iodine, iron, zinc and vitamin B-12), it may be that there are specific micronutrient deficiencies that impact particular aspects of attention. Future studies may want to investigate which combinations of nutritional variables may account for the greatest amount of variability in predicting attention performance.

A longitudinal investigation of the impact of several nutritional deficiencies on various types of cognitive skills, including attention, would also be useful. Nutrition has been associated with clinical variables, such as ADHD (Curtis & Patel, 2008). Therefore, a longitudinal study investigating early nutritional and attention predictors of diagnostic criteria may be useful for nutritional intervention planning and early identification of infants at risk for the development of attention-deficit disorders. Considered broadly, this type of research could be helpful in creating interventions and policy guidelines for supplementation.

Exploratory Analysis: Longitudinal Relations across Variables

The exploratory analysis of relations between 6-month growth/iron status and 9-month attention yielded null results. This may be due to the lesser severity of nutritional deficiencies at 6-months-of-age, the lesser impact of these variables on cognitive performance at 6 months, or the later development of endogenous attention resulting in non-significant relations to nutritional variables at earlier periods in infancy.

Weaknesses/Limitations

Although the aforementioned implications are notable, they should be interpreted within the context of limitations of the current study. In particular, data at both ages were obtained from videotapes of procedures originally intended to measure emotional responses to different situations, not attention variables. The particular episode coded for the present study was intended to assess activity level, with the primary variables of interest being touching and handling the various toys. Thus, the camera angles were not always optimal for assessing an infant's looking behavior. Nevertheless, the fact that inter-rater reliability was .88 at 6 months and .91 at 9 months attests to the likelihood that looking behavior was accurately coded. It might also be argued that use of a stopwatch and measuring to only the nearest second reduced sensitivity. Again though, the high inter-rater reliabilities attest to coding accuracy.

Additionally, birth dates are not recorded or given the same emphasis in rural Ethiopia as in Westernized cultures. Even with immunization records, infants' exact dates of birth could not be confirmed. Therefore, there may be error in these calculated ages. There were also suspected nutritional deficiencies (e.g. zinc, iodine, and protein) that were not assessed and

more sensitive tests of iron status (e.g., ferritin or transferrin receptor concentrations, as opposed to hemoglobin used in the current study) may result in more robust findings. Also, factors known to be related to attention performance such as preterm delivery, iron supplementation, infections, and treatment for such infections are known to occur in this area. Although we did attempt to screen for preterm birth, illness, and malarial infection, it is possible that these factors may have served as confounds to some extent within the current study. This sample also had very homogenous sociodemographic characteristics and it was therefore inappropriate to use such characteristics as moderators to the relations between attention and nutrition as is typically done (e.g., Wachs, 1995, Wachs, 2007, Walker et al., 2007). Therefore, there may be other factors – sociodemographic or otherwise – that account for common variance of which we were not aware.

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Table 1

Descriptive statistics for anthropometry, hemoglobin concentrations, and attention variables

	N	M	SD
Hb at 6 mos (g/dL)	87	11.74	1.31
WAZ at 6 mos	89	−0.21	1.05
LAZ at 6 mos	88	−0.90	1.32
HCZ at 6 mos	89	0.83	0.93
Total Duration of Looking at 6 mos. (sec)	89	143.30	31.91
Number of Attention Shifts at 6 mos.	89	23.94	9.59
Mean Looking at 6 mos. (sec)	89	6.81	3.26
Total Duration of Inattention at 6 mos. (sec)	89	35.15	30.90
Number of Inattention Periods at 6 mos.	89	7.30	4.40
Mean Inattention at 6 mos. (sec)	89	5.16	5.59
Hb at 9 mos (g/dL)	83	11.62	1.48
WAZ at 9 mos	84	−0.81	1.13
LAZ at 9 mos	84	−1.62	1.27
HCZ at 9 mos	83	0.41	0.97
Total Duration of Looking at 9 mos. (sec)	85	141.90	24.72
Number of Attention Shifts at 9 mos.	85	26.33	7.30
Mean Looking at 9 mos. (sec)	85	5.66	1.31
Total Duration of Inattention at 9 mos. (sec)	85	38.16	24.70
Number of Inattention Periods at 9 mos.	85	9.25	3.91
Mean Inattention at 9 mos. (sec)	85	4.34	2.85

Note. The following acronyms are included in the table: Hb (hemoglobin), WAZ (weight-for-age z-score), LAZ (length-for-age z-score), and HCZ (head-circumference-for-age z-score).

Table 2

Correlations of attention variables at 6 months with Hb and anthropometry at 6 months

		Total Duration of Looking	Number of Attention Shifts	Mean Looking	Total Duration of Inattention	Number of Inattention Periods	Mean Inattention
Hb	Pearson Correlation	0.08	0.03	0.04	-0.13	-0.02	-0.11
	<i>p</i>	.493	.771	.750	.230	.852	.323
	<i>N</i>	87	87	87	87	87	87
WAZ	Pearson Correlation	-0.03	-0.12	0.00	-0.04	0.07	-0.02
	<i>p</i>	.754	.280	.972	.704	.499	.867
	<i>N</i>	89	89	89	89	89	89
LAZ	Pearson Correlation	0.17	0.11	-0.13	-0.21*	0.13	-0.25*
	<i>p</i>	.106	.299	.235	.046	.218	.017
	<i>N</i>	88	88	88	88	88	88
HCZ	Pearson Correlation	0.06	-0.03	0.03	-0.06	-0.06	-0.03
	<i>p</i>	.579	.779	.764	.598	.561	.760
	<i>N</i>	89	89	89	89	89	89

*
p < .05*Note.* The following acronyms are included in the table: Hb (hemoglobin), WAZ (weight-for-age z-score), LAZ (length-for-age z-score), and HCZ (head-circumference-for-age z-score).

Table 3

Correlations of attention variables at 9 months with Hb and anthropometry at 9 months

		Total Duration of Looking	Number of Attention Shifts	Mean Looking	Total Duration of Inattention	Number of Inattention Periods	Mean Inattention
Hb	Pearson Correlation	−0.05	−0.17	0.23 *	0.05	0.00	−0.04
	<i>p</i>	.676	.119	.039	.683	1.000	.751
	<i>N</i>	83	83	83	83	83	83
WAZ	Pearson Correlation	0.05	0.18	−0.19	−0.05	0.02	−0.16
	<i>p</i>	.672	.111	.089	.686	.851	.145
	<i>N</i>	84	84	84	84	84	84
LAZ	Pearson Correlation	−0.01	0.11	−0.12	0.01	−0.01	−0.07
	<i>p</i>	.911	.304	.287	.909	.961	.542
	<i>N</i>	84	84	84	84	84	84
HCZ	Pearson Correlation	−0.08	−0.17	0.14	0.08	0.01	0.05
	<i>p</i>	.478	.122	.223	.474	.928	.682
	<i>N</i>	83	83	83	83	83	83

*
p < .05*Note.* The following acronyms are included in the table: Hb (hemoglobin), WAZ (weight-for-age z-score), LAZ (length-for-age z-score), and HCZ (head-circumference-for-age z-score).

Table 4

Regression coefficients using 9-month Hb and anthropometry to predict mean looking time (a) and shifts in attention (b) at 9 months

Model a. Mean looking time	Unstandardized Coefficients		Standardized Coefficients		Correlations		
	B	Std. Error	Beta	t	p	Zero-order	Partial
(Constant)	2.19	1.19		1.84	0.070		
Hb	0.26	1.00	0.28	2.65	0.010*	0.23	0.29
WAZ	-0.29	0.16	-0.24	-1.84	0.070	-0.19	-0.21
LAZ	-0.07	0.14	-0.07	-0.53	0.599	-0.12	-0.06
HCZ	0.32	0.15	0.23	2.12	0.038*	0.13	0.23
Unstandardized Coefficients							
Standardized Coefficients							
Correlations							
Model b. Shifts in attention							
Unstandardized Coefficients							
Standardized Coefficients							
Correlations							
(Constant)	42.66	6.52		6.55	0.000		
Hb	-1.13	0.53	-0.23	-2.14	0.036*	-0.16	-0.24
WAZ	1.67	0.87	0.25	1.93	0.058	0.22	0.21
LAZ	0.55	0.77	0.09	0.72	0.472	0.15	0.08
HCZ	-2.01	0.82	-0.27	-2.46	0.016*	-0.17	-0.27

* $p < .05$

Note. The following acronyms are included in the table: Hb (hemoglobin), WAZ (weight-for-age z-score), LAZ (length-for-age z-score), and HCZ (head-circumference-for-age z-score).