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The eyes have it: infant gaze as an indicator of hunger and satiation.

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Abstract

Infant gaze serves as a measure of attention to food cues in adults and children and may play a role in signalling infant hunger and satiation. Maternal responsiveness to infant satiation cues, including gaze, supports healthy appetite development and may reduce obesity risk. However, mothers often experience difficulty in interpreting feeding cues, and there have been few attempts to study cues systematically. This study aimed to develop a reliable coding scheme for categorising and tracking infant gaze behaviours during complementary feeding (CF). Twenty infants aged between six and eighteen months were filmed during typical meals on two occasions at home. The Infant Gaze at Mealtime (IGM) coding scheme was devised from the analysis of a sample of videos, a piloting and testing process, and the feeding cues and developmental psychology literature. Inter and intra-rater reliability tests of the scheme with 20% of the study videos revealed high levels of reliability. When applied to the full sample of 225 video clips, the IGM coding scheme revealed a significant decrease over time in the frequency of infants gazing at food and a significant increase in exploratory gaze behaviour within a meal. These changes were consistent across main and dessert courses, suggesting they may be indicative of changes in infant feeding state. The results suggest that infant gaze may offer a means of identifying infant hunger and satiation and, as an easily observed behaviour, an effective tool for mothers and professionals for promoting responsive feeding.

Key words: Infant gaze, feeding cues, hunger, satiation, communication, coding scheme, responsive feeding

Key messages: Infant gaze may be used as a means to identify infant hunger and satiation and may assist in the development of responsive feeding interventions.

Introduction

Gaze plays a central role in human communication. It is a key non-verbal cue for understanding others' intentions and emotions and is used by both adults and children in managing social interactions (Trevarthen & Aitken, 2001). Gaze is also used by infants to anticipate the actions of others; to regulate arousal in social interactions; to initiate joint attention, and as a medium for making non-verbal requests (Crais et al., 2009; Stifter & Moyer, 1991). Furthermore, infant gaze provides caregivers with important information regarding infant state and interest, particularly before they develop the capacity to communicate intentionally (Coupe-O'Kane & Goldbart, 1998; Cronin & Mandich, 2015).

Studies have shown that gaze and the visual processing of food images are important indirect indicators of hunger and satiation. These suggest that visual attention to food varies with hunger and satiation, and between individuals of different weights. Nijs et al. (2010) used eye tracking and a visual probe task to examine attention to pictures of food during hunger and satiation in overweight and normal weight adult females. They found no differences between groups or conditions in the eye-tracking data. However, the visual probe task showed greater automatic orientation by participants towards food cues in hungry versus satiated states, and by overweight versus normal-weight participants.

Research suggests that gaze also provides a measure of interest in food in children. In a study which controlled for hunger, Folkvord et al. (2015) investigated the impact of food advertising on children's intake of snacks. They found that children who showed a longer gaze duration for food cues in a digital advertising game, ate more of an advertised snack than those who were not attentive to the cues.

Although evidence suggests that gaze and the visual processing of food cues may differ by weight and hunger status in adults and children, gaze has received little attention as a marker of infant feeding state in the research literature. A small body of research exists regarding mothers’ perceptions of hunger and satiation cues. Within this, mothers’ reports tend to describe feeding cues in terms of mouth behaviours (e.g. mouthing food); vocal behaviours (crying or verbal requests) and bodily movements (reaching for food, pushing food away) (Skinner et al., 1998; Hodges et al., 2008). This suggests that gaze is not perceived as important by mothers in the signalling of hunger or satiation. However, there are some indications that this aspect of behaviour is involved in the communication of infant feeding state. Qualitative research by Anderson et al. (2001) concerning mothers’ assessment of infants’ readiness for weaning, found infants’ visual interest in others’ food was one signal that mothers used to determine their babies’ readiness for the introduction of CF. Meanwhile, mothers in the study by Hodges et al. (2008) identified ‘staring’ as a hunger cue. However, this was cited ‘infrequently’ and no further detail on the behaviour was provided.

Gaze has also received some limited attention within a small number of observational studies investigating behaviours associated with infant hunger and satiation under controlled conditions. Like maternal report studies, these have tended to focus on motor movements (hand movements) and mouth behaviours (sucking) during hunger and satiation, rather than gaze (Lew & Butterworth, 1995; Turkewitz et al., 1966). However, Paul et al. (1996) examined infant gaze in conditions of hunger and satiation, alongside movement and sucking behaviours. They found significantly higher eye movement frequencies and longer durations of visual exploration of objects before and after milk feeds in infants of 18 weeks of age and older, compared with those during feeding. They did not find significant differences between pre and post prandial gaze. The frequency of infant eye movements and the duration of visual exploration therefore appear to be lower during feeding than outside of feeding.

While Paul et al (1996) did not detect differences between pre and post prandial gaze in milk fed infants, one study has identified significant changes in gaze behaviour in hungry and full infants. An experimental study by Gerrish and Menella (2000) examined the responsiveness of 13 four to six-month-old infants to a rotating, musical mobile before and after breastfeeds by examining frequency of limb movements and duration of gaze at the mobile when switched on and off at one minute intervals on two separate days. The authors found no significant differences in limb activity in pre and post prandial states. However, the infants looked at the mobile significantly longer after breastfeeding than prior to breastfeeding, thereby suggesting that gaze may serve as an indicator of infant feeding state in milk fed infants of the age tested in the study. Specifically, greater interest after feeding suggests a shift in attention towards the mobile during the fed state.

Given indications that gaze differs with infant feeding state, and the key role that it plays in infant communication, it seems likely that a systematic examination of this behaviour may provide new insights into the signalling of infant hunger and satiation. The current lack of studies in the area, however, means there are no tools for investigating gaze change during infant feeding. There are brief references to infant gaze in some responsive feeding measures. For example, gaze aversion is identified as a potent disengagement cue in the Nursing Child Assessment Satellite Training (NCAST) Feeding Scale (Sumner & Spitz, 1994) and visual attentiveness to the caregiver is regarded as an indicator of infant feeding responsiveness in the Responsiveness to Child Feeding Cues Scale (Hodges et al., 2013). However, these scales serve primarily as measures of caregiver feeding responsiveness, and they do not offer a means of following or measuring infant gaze across meal episodes. The present study therefore had three aims: (1) to develop a reliable coding scheme to track infant gaze across mealtimes, (2) to test the feasibility of applying the coding scheme to mealtime gaze behaviours, (3) to use the scheme to examine gaze behaviour change across an infant feeding episode. A decision was taken to develop and test the scheme in the context of CF rather than milk feeds, given infants' greater trunk and head stability beyond the age of six months; also, gaze is easier to observe during CF as a consequence of infants' upright posture and, because the limited work regarding infant gaze and feeding state to date, has only been conducted in the context of milk feeding. The development of a reliable measure of gaze during CF would enable researchers to investigate whether changes in this behaviour reflect underlying processes of hunger and satiation development during a feeding episode, and would highlight which, if any, aspects of gaze are most associated with infant hunger and fullness. Results from such work would be helpful in extending our understanding of infant feeding cues and may assist with the development of responsive feeding interventions.

In pursuing the development of the gaze coding scheme, it was assumed that differing frequencies of gaze behaviour during feeding would provide insights into infant feeding state. Specifically, it was assumed that behaviours observed frequently at the start of feeding would be associated with hunger, while those observed later would be associated with satiation. Within this, it was hypothesised that:

1. Gaze behaviour would change across the meal away from gazing at food towards non-feeding related gaze in common with patterns of post-ingestive behaviour in animals (i.e. the behavioural satiety sequence, Rodgers, Holch, & Tallett, 2010).

2. Higher frequencies of hunger related gaze (gazing at food) would be seen in main than dessert courses (if offered) as a result of higher levels of hunger earlier in the meal.

3. Similar patterns of gaze change would be seen between main and any dessert courses as a result of sensory specific satiety effects i.e. the decline in appetite for a particular food after eating it for a period of time, and the renewal of appetite on exposure to a food with different sensory qualities (flavour, texture etc.) (Rolls, Rowe, & Sweeney, 1981).

4. Gaze aversion from food, as a form of rejection, would increase in frequency as the meal progressed.

Participants

Flyers containing study information were sent to day nurseries and mother and baby groups in Leeds, England and surrounding areas. Twenty mother-infant dyads were recruited. Infants were eight males and twelve females between six and eighteen months old at the time of entry into the study (mean age 11.7 months ± 3.40). Seven infants had been fed using baby led weaning principles (BLW[1])(as defined by their mothers), One BLW mother reported occasional use of a spoon to feed yoghurt and to start meals. The remaining four BLW mothers reported using only independent feeding or use of a loaded spoon for the infant to self-feed. Thirteen infants had been fed using traditional spoon feeding (SF) followed by more independent feeding with increasing age. All infants had been breastfed at birth for at least a few days. Mean breastfeeding duration was 24.89 weeks (± 15.96). Six mothers continued to breastfeed at the time of the study. Mean weaning age was 22.2 weeks (± 1.85). Mothers were aged between thirty and forty-three years of age (mean age 34.6 ± 3.23). Nine were first time mothers and all but two had an undergraduate degree or higher educational qualification. Mothers gave consent for their infants to participate in the study and ethical approval for the research was granted by the School of Psychology Ethics Committee at the University of Leeds reference: 14-0010.

Method

The study had four phases; phase 1 involved filming two separate feeding episodes between mothers and their infants; phase 2 involved development, piloting and revisions to the coding framework along with piloting of the coding method (continuous or instantaneous coding). This phase used video recordings taken in phase 1 and video recordings taken from an earlier research study. Phase 3 involved formal reliability testing using a sample of 20% of the footage

[1] Baby led weaning refers to the practice of infants feeding independently on whole foods as soon as CF is introduced.

of videos from phase 1 along with final revisions of the coding scheme itself. Phase 4 involved the coding of the entire video data set and related analyses.

Phase 1

Data collection

Participants were visited three times at home. At the first visit, demographic details and a feeding history were taken. At visits two and three, infants were video recorded eating a familiar meal at their usual lunchtime. The mean time between filming visits was sixteen days (±12.80). Mothers were asked to not feed their babies for at least an hour before filming and to avoid any substantial intake of food or drink before this to ensure that infants were hungry before the meal. During filming mothers were asked to serve a familiar and liked meal in line with normal feeding practice and to ignore the presence of the researcher. Most infants (n = 16) ate dessert as well as a main course at both filming visits and both courses of the meal were filmed accordingly. Wherever possible, filming took place in the absence of siblings to minimise interruptions to the meal. However, an older sibling was present during filming with one family.

Meals were filmed using a Panasonic SDR-H90 video camera and filming commenced with the seating of the infant in the high chair or at the table. The majority of mothers sat opposite their infants during filming, with short periods of time away from the infant for food preparation, clearing up dishes and general activities. One of the mothers did not sit with her infant during the meal but interacted with the infant between bouts of food preparation. Filming ended when mothers indicated that the meal was finished.

Phase 2

Development of codes

The initial development of the Infant Gaze at Mealtime (IGM) coding scheme was largely informed by observations of a sample of five study videos and five other infant feeding videos from an earlier project which were available to the first author. Observational codes were developed largely as descriptions of gaze direction during the feeding episode e.g. 'gazes at food, gazes at drink etc.' (Table 1). The code 'gazes at other' was used to describe instances of the infant gazing at non-feeding related items and the infant gazing at the camera. Infants were also observed to gaze at the caregiver during feeding. The code 'gazes at caregiver' was therefore also included to describe gaze direction and on the basis that visual attentiveness to the caregiver appears as an indication of feeding responsiveness in the RCFCS (Hodges et al., 2013).

Behaviour	Modifier	
Unobservable	n/a	
watches caregiver	n/a	
gazes at caregiver	i) spontaneously	ii) prompted
gazes at drink	i) spontaneously	ii) prompted
gazes at food	i) spontaneously	ii) prompted
gazes at other	i) spontaneously	ii) prompted
active gaze aversion	n/a	

Table 1 - First version of gaze codes

Two further descriptions of infant gaze were also included in the initial coding scheme: 'watches caregiver' where the infant's gaze followed the caregiver's movements for example around the kitchen (rather than gazing directly at the caregiver's face); and 'active gaze aversion' where infants were observed to avert their gaze in direct response to offers of food. The inclusion of this code was also informed by its identification as a disengagement cue in the NCAST feeding scales (Sumner & Spitz, 1994). Finally, an 'unobservable' code was included for instances where the infant's eyes were obscured, making the identification of gaze direction/gaze behaviour impossible. Modifiers were included in the initial coding scheme for gazing at the caregiver, gazing at food and gazing at other objects, to identify whether gaze was directed to these spontaneously, or whether it was prompted, for example by the caregiver drawing the infant's attention to an item or to herself. Descriptors were developed alongside all behaviour codes to provide additional details for coders regarding the appropriate use of codes.

Piloting of codes

The usability of the initial IGM was assessed by piloting codes individually with entire videos from the first filming visit for five of the participants (89.23 minutes of footage in total). These videos were observed to assess the feasibility of coding gaze and to ensure that codes captured gaze behaviours comprehensively. Following this pilot, a number of changes were made to the first version of the scheme (Table 2). First, the IGM was simplified by removing the 'spontaneous or prompted' modifiers for 'gazes at caregiver', 'gazes at drink', ' gazes at food' and ' gazes at other'. During piloting the vast majority of gaze shifts were observed to be infant initiated, and the inclusion of modifiers therefore made coding unnecessarily time-consuming. Furthermore, there were also occasions where the categories proved unworkable, for example, it was difficult to categorise gaze shifts to the caregiver as being unequivocally spontaneous or prompted if they were part of an ongoing social exchange.

Behaviour	Descriptor
Unobservable	View of infant's eyes is obscured
watches caregiver	Infant watches caregiver activity
gazes at caregiver	Infant gazes at caregiver's face
gazes at drink	Infant gazes at own or other drink
gazes at food	Infant gazes at own or other food
gazes at other	Infant gazes at item other than food, drink or caregiver
exploratory gaze	Infant engages in intent gazing at feeding utensils, food remnants or other objects while touching or manipulating them.
active gaze aversion	Infant actively averts eyes and face from care-giver in response to offer of food

Table 2 – The revised coding scheme

The second change involved the addition of a new code. Infants were observed to engage in a type of gaze behaviour which was not yet captured by any code, whereby they would gaze intently at objects such as feeding utensils, remaining pieces of food or objects such as empty yoghurt pots, while actively manipulating them (e.g. turning, squeezing, etc.). The developmental psychology literature indicates that such visual examination is associated with exploratory play (Ruff & Salterelli, 1993) and a new code of ‘exploratory gaze’ was therefore added.

Piloting of coding method

Following revision of the IGM, a second round of piloting was conducted to establish the most feasible method for coding, i.e. whether to code continuously or to use instantaneous sampling. The main observer (JM) and a second trained observer coded footage from the main courses of five selected films from phase one on a continuous basis. Films were selected in order to observe infants from a range of different ages between 6 and 14 months. The first, middle and last twenty percent of main course footage was used. Fifteen video sections of between 1.53 and 4.74 minutes length were coded with a total of 46 minutes of film coded. The same observers then coded the same films using an instantaneous sampling frame of three seconds, i.e. frozen images were coded every three seconds. Discussions of pilot coding indicated that instantaneous sampling offered a more feasible coding method than continuous sampling and therefore one which was more likely to be reliable. Instantaneous sampling enabled coders to observe and interpret behaviours from relatively clear, frozen images every three seconds. In contrast, coders encountered difficulty coding gaze shifts continuously, as these were often subtle and fleeting. A decision was therefore taken to use the instantaneous sampling method for coding. The test interval of three seconds was retained; this allowed for frequent observation of infant gaze whilst reducing the risk of missing behaviours and minimizing burden on coders.

Phase 3

Formal reliability testing

Filmed meal episodes were divided into main and dessert courses. The mean length of main course videos was 14.46 minutes and the mean length of dessert course videos was 7.31 minutes. As with the procedure for testing different coding strategies, each course was then divided into the first, middle and last twenty percent of course footage as a sampling strategy. This resulted in between 6 and 12 video sections per infant across the two filmed feeding episodes, depending on whether infants had eaten a dessert course as well as a main on both filming visits (n =16). A stratified random sample of videos was selected for reliability testing which included only infants who had consumed both a main and dessert course at each filming visit, and equal numbers of spoon fed and baby led weaned infants. The sample contained the video sections for four participants (20% of the participant group) and comprised 48 video clips out of a possible 225. These varied between 2.33 and 17.83 minutes in length.

Videos were coded using Noldus Observer XT video analysis software using a fully crossed design and two under-graduate second coders. The order in which video clips were coded was determined using a random number generator. Second coders received training, practice and feedback sessions in coding before carrying out independent coding on half of the sample videos (n = 24). Initial inter-rater reliability calculations were carried out on the raw data from this subset of the reliability sample using the Noldus Observer XT reliability calculation facility. This provides Pearson's correlation data between coders for all observations combined, as well as Figures for individual observations. This output was used to identify instances of poor inter-rater agreement on individual coding. Pearson's correlation of 0.70 is considered acceptable as an inter-rater reliability value for exploratory studies (Stemler & Tsai, 2008). Videos for individual observations with correlation coefficients lower than 0.70 were therefore reviewed by all three coders and areas of disagreement were discussed. Some of the coding scheme descriptors were also developed at this point (gazes at caregiver, gazes at other and exploratory gaze) in order to provide additional details regarding the appropriate use of codes. The second coders then re-coded videos clips for which agreement had fallen below the 0.70 threshold until a Pearson's correlation of at least 0.70 was attained with the main coder. This process was repeated for the second half of the reliability film clips until all observations achieved correlation coefficients of at least 0.70 for all video observations between the main and second coders.

Pearson's correlations provide information about the strength of a relationship between two sets of ratings rather than actual agreement between sets of ratings (Stolarova, Wolf, Rinker and Brielmann, 2014). As such, while useful for coder training and feedback, they are not considered the best option for final reliability analyses (Bakeman and Quera, 2011). Final analyses were therefore conducted using two-way mixed effects, single measure intra-class correlations (ICCs) for absolute agreement across all behaviour codes on all observations, and absolute agreement on individual codes across all observations. The ICCs were carried out using square root transformed data, as observational coding data were not normally distributed (Hallgren, 2012).

Test-retest reliability analyses were also performed to assess the reliability of the IGM over time. The same sample of 48 film clips was re-coded by the main coder 20 weeks after the initial coding session. Again, two-way mixed effects intra-class correlations were conducted with transformed data for absolute agreement. Analyses were carried out to examine total agreement across all observations in the reliability sample at the first and second coding, and for each of the individual gaze behaviour codes at the first and second coding.

Phase 4

The same procedure was followed for video analysis as for phase 3 with meal videos divided into mains and desserts and further sub-divided into the first, middle and last twenty percent of course footage. 225 video sections of between 26 and 355 seconds in length were coded using Noldus Observer. As with phase 3, videos were coded in random order.

Treatment of data in phase 4

Following coding of the complete data set data for Gazing at Drink were removed as these were considered to reflect infant thirst rather than being relevant to behavioural change associated with hunger and satiation. Mean frequency scores were calculated between meals 1 and 2 for remaining gaze behaviours at the three time points of the main and dessert courses. This produced one set of figures for analysis for each course section. Mean frequencies, ranges and standard deviations were then calculated for each type of gaze behaviour across meals as a whole and for the three time points of mains and dessert courses.

Inferential analyses for main and dessert course data began with the square root transformation of frequency data to address the issue of the differing video lengths across different infants, meals and courses. Transformed data were normality tested using Shapiro Wilks analyses to determine the appropriateness of subsequent parametric and non-parametric analyses. Assumptions tests were also conducted to determine appropriate non-parametric tests. Analyses of change were conducted between the hungriest and most satiated parts of the meal (the first 20% of main courses and the last 20% of dessert courses) using repeated measures ANOVAs, Wilcoxon's signed rank or Sign tests as appropriate. Three-way factorial repeated measures ANOVAs with Bonferroni corrections were conducted to assess main effects for gaze, time and course for the transformed whole meal data as no non-parametric equivalent exists for such analyses. These were followed by two-way ANOVAs to examine the main effects of time and gaze within main and dessert courses. One-way ANOVAs and Friedman's tests were subsequently used to examine individual behaviours at course level. Finally, significant results from these analyses were subjected to pairwise and Wilcoxon Signed Ranks tests as appropriate. All non-parametric tests were conducted using raw data and exact significances. Critical values were adjusted using Bonferroni corrections for multiple Wilcoxon comparisons to control familywise error rate.

Results

Inter-rater reliability

Intra-class correlations across all 48 observations were in the excellent range, ICC= .95 with a 95% confidence interval from .95 to .96 (F (383,766) = 58.70 p < .001) (Cicchetti, 1994). Intra-class correlations for individual gaze codes were good to excellent (Table 3).

Behaviour	ICC (single measures)	95% Confidence Interval		F Test with True Value 0
		Lower Bound	Upper Bound	
unobservable	.74	.62	.84	F (47,94) = 10.60, p < .001
watches caregiver	.91	.86	.95	F (47,94) = 31.16, p < .001
gazes at caregiver	.96	.94	.98	F (47,94) = 78.68, p < .001
gazes at drink	.86	.80	.92	F (47,94) = 20.37, p < .001
gazes at food	.93	.89	.96	F (47,94) = 40.69, p < .001
gazes at other	.95	.91	.97	F (47,94) = 54.63, p < .001
exploratory gaze	.88	.81	.92	F (47,94) = 22.41, p < .001
active gaze aversion	.84	.82	.93	F (47,94) = 24.65, p < .001

Table 3 – Inter rater intra-class correlations for individual gaze codes

Test-retest reliability

Test-retest intra-class correlations across all 48 observations were in the excellent range, ICC= .97, with a 95% confidence interval from .97 to .98 (F (383,383) = 95.31 p < .001). Intra-class correlations for individual gaze codes were all in the excellent range (Table 4).

Behaviour	ICC (single measures)	95% Confidence Interval		F Test with True Value 0
		Lower Bound	Upper Bound	
unobservable	.99	.99	.99	$F (47,47) = 488.51, p < .001$
watches caregiver	.99	.99	.99	$F (47,47) = 462.06, p < .001$
gazes at caregiver	.98	.98	.99	$F (47,47) = 185.79, p < .001$
gazes at drink	.92	.86	.96	$F (47,47) = 23.84, p < .001$
gazes at food	.94	.90	.97	$F (47,47) = 33.75, p < .001$
gazes at other	.98	.96	.99	$F (47,47) = 91.23, p < .001$
exploratory gaze	.94	.90	.97	$F (47,47) = 32.13, p < .001$
active gaze aversion	.94	.89	.97	$F (47,47) = 30.85, p < .001$

Table 4 – Test-retest intra-class correlations for individual gaze codes

Whole meal descriptive statistics

Gazing at other showed the highest mean frequency across the six time points of the whole meal (Table 5). This was also the most variable behaviour. Gazing at food showed the second highest mean frequency whilst the lowest mean frequency was seen in active gaze aversion.

Behaviour	N (Time points)	Range	Mean	Std. Deviation
active gaze aversion	6	0 - 0	0.11	0.13
exploratory gaze	6	1 - 8	4.26	2.62
gazes at caregiver	6	3 - 10	6.51	2.64
gazes at food	6	4 - 13	9.05	3.24
gazes at other	6	9 - 21	15.32	5.67
watches caregiver	6	1 - 7	2.89	2.31

Table 5 – Mean Gaze Frequencies Across Whole Meals

Main course descriptive statistics

Mean frequencies of exploratory gaze and gazing at the caregiver increased at all three time points during the main courses while those of gazing at food and watching the caregiver decreased. There were no discernible patterns of change for other gaze behaviours across time in the main courses.

Dessert course descriptive statistics

Mean frequencies of gaze aversion from food, gazing at the caregiver, and gazing at other increased over time in the dessert courses and gazing at food and watching the caregiver decreased. No other patterns of gaze change were observed.

Time1 to Time 6 ANOVAs and Wilcoxon's Test

Repeated measures ANOVAs of gaze change between the hungriest and most satiated parts of the meal (the first and last 20%) revealed highly significant decreases over time in the frequency of Gazing at Food, F (1,15) = 23.14, p < .001, ηp^2 = .61 and Gazing at Other, F (1,15) = 10.22, p = .001, ηp^2 = .41 and a significant increase in time in the frequency of exploratory gaze, F (1,15) = 5.14, p = .039, ηp^2 = .26. Wilcoxon's signed ranks tests also revealed a highly significant median decrease in watching the caregiver, Z = -3.02, p =.001. No other significant changes in gaze behaviour were observed between Times 1 and 6.

Whole Meal ANOVAs

Three-way repeated measures ANOVAs revealed a highly significant main effect for course, F (1,15) = 26.42, p < .001, ηp^2 = .64, indicating that gaze behaviours as a whole differed between main and dessert courses. A highly significant main effect was also shown for behaviour, F (6,90) = 59.43, p < .001, ηp^2 = .80 thereby indicating that different types of gaze behaved differently during meals, i.e. the independence of different behaviours. Highly significant interactions were also found for course by behaviour, F (6,90) = 3.62, p = .003, ηp^2 = .19 and behaviour by time (after the application of the Greenhouse Geisser correction), F (6.13,91.98) = 12.19, p < .001, ηp^2 = .45. As such, overall gaze behaviour was seen to vary both by course and by time.

Whole meal ANOVAs of individual types of gaze by course found significantly higher frequencies of a number of gaze behaviours in main than dessert courses, i.e. gazing at food: $F(1,15) = 5.41$, $p = .034$, $\eta p^2 = .27$; gazing at the caregiver: $F(1,15) = 10.22$, $p = .006$, $\eta p^2 = .41$; gazing at other: $F(1,15) = 22.31$, $p < .001$, $\eta p^2 = .60$ and watching the caregiver: $F(1,15) = 5.14$, $p = .039$, $\eta p^2 = .26$.

Main Course ANOVAs and Friedman's tests

A significant main effect for gaze was found $F(6, 114) = 49.45$, $p < .001$, $\eta p^2 = .72$ indicating that different forms of gaze behaved differently during the main courses of meal. Mauchly's test was significant for the interaction between gaze and time. This was found to be significant on the application of the Greenhouse-Geisser correction, $F(12, 100.60) = 8.31$, $p < .001$, $\eta p^2 = .30$ showing that gaze frequency changed with time for some types of gaze behaviour.

Repeated measures ANOVAs did not show significant results for gazes at caregiver and gazes at other. However, a highly significant result was found for Gazes at food $F(2,38) = 8.572$, $p = .001$, $\eta p^2 = .31$, with a significant decrease in the frequency of this behaviour over time (Figure 1).

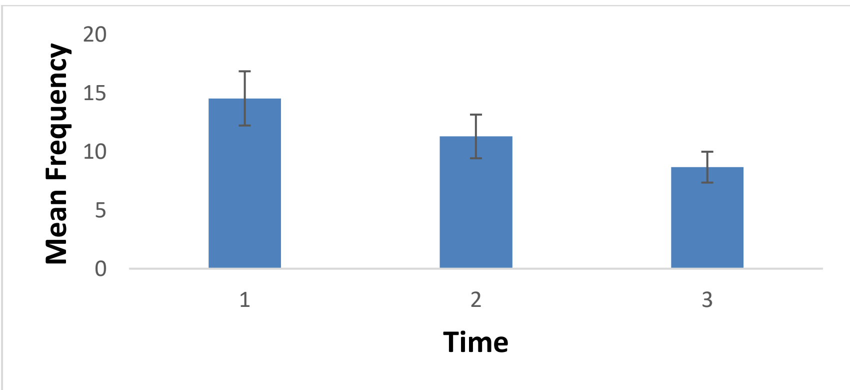

Figure 1 – Main Course Gazing at Food Mean Frequencies and Standard Errors

Pairwise comparisons indicated that significant differences in gazing at food occurred between time 1 and time 2 (p = .029) and time 1 and time 3 (p = .002). No significant difference was observed between times 2 and 3.

Friedman's tests revealed a significant increase in the frequency of exploratory gaze over time, X^2 (2) = 18.47, p < .001 (Figure 2). Post hoc Wilcoxon signed-rank tests found a significant increase over time for exploratory gaze behaviour between times 1 and 2, Z = -3.53, p < .001 and times 1 and 3, Z = -3.38, p < .001, but not between time 2 and time 3. Therefore, infants' interest in exploring increased by the second half of the meal and remained high relative to the beginning of the course.

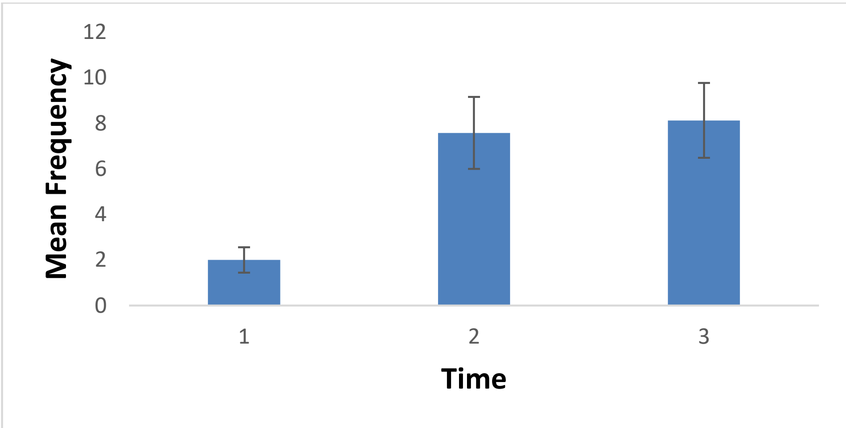

Figure 2 – Main Course Exploratory Gaze Mean Frequencies and Standard Errors

A highly significant median decrease was also observed in the frequency of watching the caregiver over time, X^2 (2) = 9.51, p = .007 (Figure 3). Wilcoxon signed-rank tests showed significant decreases in the frequency of this behaviour between times 1 and 2 (Z = -2.36, p = .008) and 1 and 3, Z = -2.63, p = .003**.** Thus, infants' gaze shifted from watching their mothers as main courses progressed. Friedman's analyses did not reveal any significant changes over time in active gaze aversion or gazing at other.

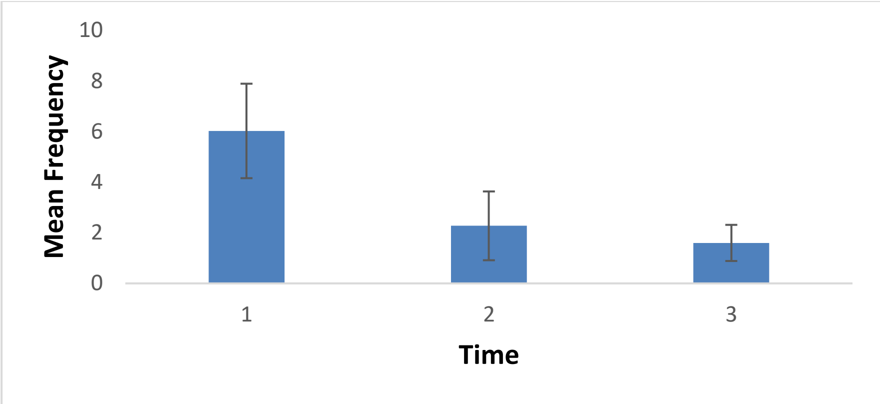

Figure 3 – Main Course Watching the Caregiver Mean Frequencies and Standard Errors

Dessert course ANOVAs and Friedman's tests

A significant main effect for gaze was found F (6, 90) = 5.74, $p < .001$, $\eta p^2 = .28$. There was also a significant main effect of time, F (2,30) = 48.46, $p < .001$, $\eta p^2 = .76$ and a significant interaction between gaze and time following application of the Greenhouse-Geisser correction, F (12, 80.77) = 33.50, $p < .001$, $\eta p^2 = .69$.

In contrast to the main courses, repeated measures ANOVAs showed a significant increase over time in the frequency of gazing at the caregiver during desserts, F (2,30) = 8.27, p = .001, $\eta p^2 = .36$ (Figure 5). Pairwise comparisons revealed that significant changes in the frequency of gazing at the caregiver occurred between times 1 and 3 (p = .005) and 2 and 3 (p = .049). Significant decreases were also observed in the frequency of gazing at food F (2,30) = 16.84, $p < .001$, $\eta p^2 = .53$ (Figure 6) with pairwise analyses identifying that these occurred between times 1 and 3, and 2 and 3 ($p < .001$ and p = .011).

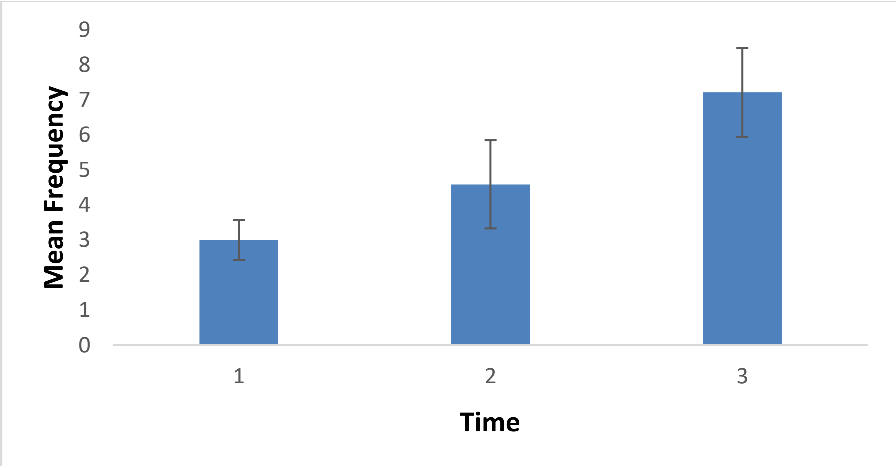

Figure 4 – Dessert Course Gazing at the Caregiver Mean Frequencies and Standard Errors

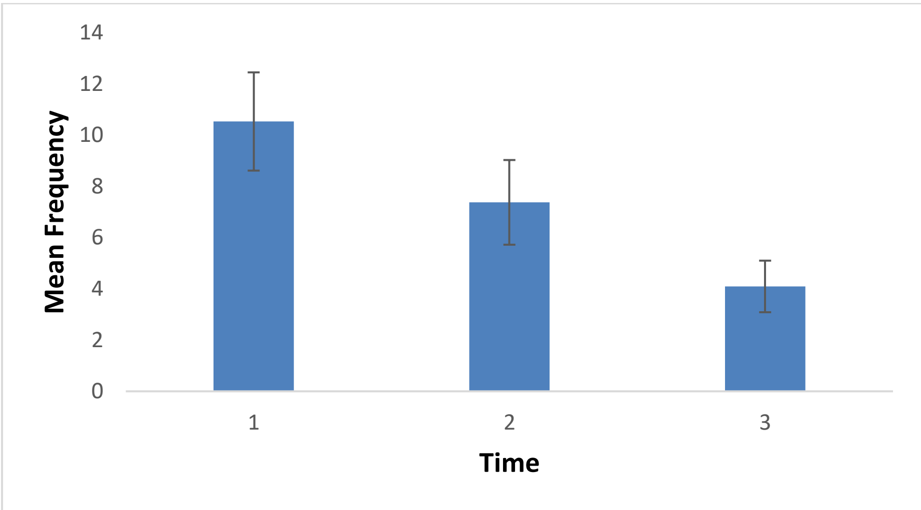

Figure 5 – Dessert Course Gazing at Food Mean Frequencies and Standard Errors

Friedman's analyses showed a significant increase in exploratory gaze behaviour over time X^2 (2) = 8.54, p = .012. Post hoc Wilcoxon signed-rank tests were conducted with a Bonferroni correction applied, resulting in a significance level of $p < 0.017$. Significant changes were identified in exploratory gaze behaviour between time 1 and time 2 (Z = - 2.81 p = .003) and time 1 and time 3 (Z = - 2.66, p = .005).

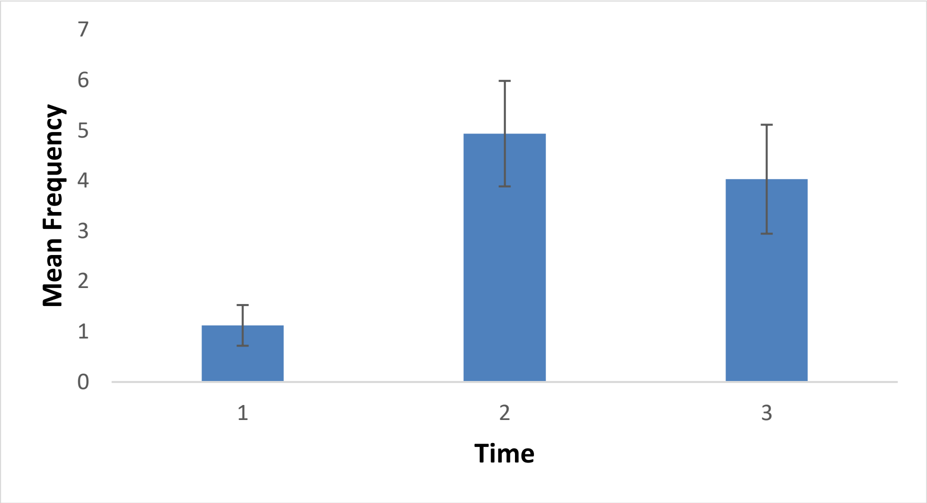

Figure 6 – Dessert Course Exploratory Gaze Mean Frequencies and Standard Errors

Discussion

This study aimed to develop and test a reliable coding system to examine infant gaze during CF. Results indicate that the scheme (the IGM) is a reliable measure and that observation of infant gaze during meals may provide insights into hunger and satiation levels. This is predicated on the assumption that gaze behaviour observed at the start of an eating episode is likely to be associated with hunger, while that observed later is likely to associated with satiation.

Reliability of the IGM

High inter- and intra-rater reliabilities were found for the IGM. These can be attributed to its comprehensiveness and simplicity in describing the orientation of infant gaze. Results are consistent with findings from earlier studies indicating that adult and infant gaze can be coded with high levels of reliability, (Harrigan, Rosenthal & Scherer, 2008; Ruff, Capozzoli & Saltarelli, 1996). The high reliability of the coding scheme is likely to arise to some degree from the conditions in which it was tested. First, the use of video coding software and instantaneous sampling facilitated the observation of relatively clear, 'frozen' images, thereby increasing coding accuracy. Second, the use of video software enabled the slowing down and repeated viewing of behaviours. Furthermore, the practice of reviewing inter-rater agreement half way through reliability coding is likely to have reduced coder drift (Martin, Bateson & Bateson, 2007).

Despite high levels of inter-rater reliability for individual behaviours, the ICC for 'unobservable' gaze was low relative to other behaviours, (in the good rather than the excellent range). The descriptor for this code may therefore benefit from refinement. Coders were instructed to use this code if both of the infant's eyes were obscured, or the direction of gaze could not be discerned. Images of infants' eyes were sometimes indistinct in video stills however, leading to disagreement between coders.

Testing and subsequent revisions of the IGM generated a scheme which described all gaze behaviours during feeding adequately. In addition, its development from naturalistic observations is also likely to ensure good external validity (Knapp et al., 2013). Despite this, there are potential threats to validity of the scheme, e.g. the removal of the 'spontaneous' and 'prompted' gaze modifiers during scheme development means it will have inevitably captured gaze shifts prompted by mothers rather than entirely infant initiated ones. The context in which videos were recorded may also have affected coding accuracy, e.g. there were times when the direction of infant gaze could not be ascertained as this was directed at items which were out of shot. Participant reactivity to the presence of the camera may also mean the frequency of some behaviours was over or under-estimated. This point made, infants appeared to be more accustomed to the camera at the second filming visit. This may have helped to mitigate reactivity.

Additional limitations to the scheme arise from the use of instantaneous sampling rather than continuous coding. This may have limited the IGM's accuracy in assessing the frequency of gaze behaviours meaning the rates and durations of different gaze behaviours could not be calculated (Martin & Bateson, 2007) and data could not be used for sequential analysis (Bakeman & Gottman, 1997).

Gaze change across eating episodes

Significant decreases were observed between the times at which we assumed the infant was hungriest and most satiated for gazing at other, watching the caregiver and gazing at food while a significant increase was noted for exploratory gaze (i.e. instances of infants gazing intently at feeding utensils, food remnants etc.) while physically manipulating them). Such behavioural changes may therefore be indicative of infant feeding state. However, only gazing at food and exploratory gazing showed consistent changes over time at course as well as meal level. Watching the caregiver showed a significant reduction over time in main courses but not desserts. This may be explained by the observation that mothers spent more time preparing food at the start of mains than desserts, with the latter largely involving pre-prepared/quickly prepared foods such as fruit or yoghurt. This provides further support for watching the caregiver as an indication of hunger and some support for hypothesis 1 as it represents a move away from feeding related to non-feeding related gaze over time. However, it should be noted that decreases in the frequency of this behaviour were not independent of mothers' actions; mothers tended to stop food preparation early in the meal/main course and then sat down, meaning there was less for infants to 'watch' as time progressed. In addition, it is unclear whether infants watched their mothers early in the main course because they were preparing food or out of general curiosity.

The significant reduction in gazing at other from time 1 to time 6 and the significantly lower frequency of this behaviour during dessert than main courses should also be interpreted cautiously. This behaviour may be indicative of hunger as, during filming, infants appeared to engage in 'looking round' early in the meal while absorbed in eating. However, no significant reduction was observed over time in this behaviour within main or dessert courses. Furthermore, as looks to the camera were coded as gazes at other, it is possible that decreases in this behaviour may have occurred in part as a result of infants becoming less interested in the camera over time.

Findings for gazing at food and exploratory gaze in meals as a whole and during separate courses both provide support for hypothesis 1 and hypothesis 2, i.e. the prediction that infants would look less at food and would engage more in non-food related gazing over time and that more hunger related gazing would be observed in the earlier stages of the meal (i.e. the main course). Findings regarding exploratory gaze also provide support for hypothesis 1, and the increase in this behaviour as main and dessert courses progressed is consistent with Gerrish and Menella's (2000) finding that infants showed greater visual attention to a mobile after, rather than before, breastfeeding, and, with parental reports of infants playing with their food as a satiation sign (Hodges et al., 2008; Hodges et al., 2016; Skinner et al., 1996). Importantly, changes in this behaviour and gazing at food also provide support for hypothesis 3 that similar patterns of gaze change would be seen between main and dessert courses as a result of sensory specific satiety (Rolls et al., 1981). Exploratory gaze increased over main courses but decreased at the beginning of desserts before resuming a generally upward trend. Similarly, decreases in gazing at food were progressive within courses but not from one course to the next, i.e. this behaviour decreased over time in the main courses but increased in frequency at the beginning of desserts before declining again.

Findings regarding the timing of changes to the frequency of gazing at food and exploratory gaze also have implications for understanding their status as markers of infant satiation. In both main and dessert courses a significant increase was observed in the frequency of exploratory gaze by the middle 20% of the course, suggesting changes in this behaviour indicate developing (rather than complete) satiation. Similarly, a significant decrease in the frequency of gazing at food was observed by the middle 20% of main courses. The same pattern was not observed for decreases in gazing at food during desserts. In these the significant decrease occurred between the middle point of the courses and the end. This may reflect differences in the presentation of food between main and dessert courses; many mothers in the study offered fruit as dessert, i.e. by giving a few berries at a time, rather than providing a ‘full dessert portion’ in one go. Alternatively, the later change in the frequency of gazing at foods between main and dessert courses may reflect an infant interest in dessert (sweet foods) which persists for longer than for savoury foods.

Findings for gazing at the caregiver were mixed. The higher frequency of this behaviour during main than dessert courses might suggest that it is associated with hunger. This would be consistent with TW infants using eye contact to indicate readiness for the next spoonful of food (Crais et al., 2009; Stifter & Moyer, 1991), thereby supporting hypothesis 2. However, a significant increase over time was observed in the frequency of gazing at the caregiver during desserts but not main courses. This would suggest this behaviour is associated with satiation and a move away from feeding related to social gaze during desserts thereby contradicting hypothesis 2. The most likely explanation for these contradictory findings is that infants use dyadic gaze for different communicative aims (requesting and social interaction) and so this behaviour may be used to signal both hunger and satiation.

Hypothesis 4 was not supported by this study as no significant reductions were observed in active gaze aversion either between Times 1 and 6 of the whole meal, or in separate main or dessert courses. This is unexpected given that gaze aversion has been identified as a potent indication of satiation in infants (Hodges, 2008; Sumner & Spietz, 1994). One would therefore expect to see this behaviour increase over time. However, the likelihood of observing gaze aversion is dependent on maternal responsiveness. It may be that mothers in this sample were relatively responsive to infant fullness thereby obviating the need for infants to display this ‘strong’ satiation cue. This is supported by sample characteristics – most mothers were well educated with relatively long histories of breastfeeding. Such characteristics are known to be associated with greater feeding responsiveness (Hodges et al. 2013). Furthermore, a third of infants in the sample were fed using BLW, while another third were feeding with some degree of independence, again decreasing the likelihood of observing gaze aversion.

Conclusion

Findings from this study indicate that gaze may provide a means to assess infant feeding state in the context of a CF episode given that changes in gaze behaviour were observed between the start of the meal, when infants were assumed to be hungriest and the end of the meal, when infants were assumed to be satiated. Within this, both gazing at food and exploratory gaze behaviour appear likely to provide insights into infant feeding state as both of these changed consistently across main and dessert courses and in line with expectations of a change from feeding to non-feeding related behaviour over time. The observation that these behaviours appeared sensitive to the effects of sensory specific satiety further suggests that they may have utility in tracking infant hunger. Meanwhile, changes in exploratory gaze may have the most potential to provide insights into hunger and satiation as, unlike other gaze types, this appears most likely to function independently of course set up or caregiver behaviour.

Notwithstanding promising findings here for the utility of gaze as a measure of infant feeding state, an important issue in the use of the IGM arises from the fact that it was developed from a small sample of infant feeding videos and tested on largely the same small sample. The sample was also somewhat homogeneous in terms of mothers' demographic characteristics. It is possible that mothers from different backgrounds may interact differently with infants at mealtimes and that this may impact on infant gaze behaviour. Further testing of the scheme is indicated therefore, to ensure that it adequately captures the gaze behaviours of a wider range of infants. Despite this, the IGM was tested in infants from a range of different ages and in the context of a range of different feeding practices (spoon feeding, baby led weaning and spoon feeding accompanied by self-feeding with finger foods). As such, it provides a starting point for investigating infant gaze behaviour during meals. It also provides a basis for researchers to establish which, if any, gaze behaviours are associated with hunger and satiation and how gaze may change over the course of a meal. Further studies using the IGM may extend our understanding of behavioural change associated with infant feeding state, and so may yield findings relevant to the development of responsive feeding interventions.

Conflicts of interest

None declared from Janet McNally, Marion Hetherington, Siobhan Hugh-Jones or Samantha Caton. Hugo Weenen and Carel Veijken are employees of Danone Nutricia Research.

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