# 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.

31

34

## Introduction

36 Gaze plays a central role in human communication. It is a key non-verbal cue for

37 understanding others' intentions and emotions and is used by both adults and children in

38 managing social interactions (Trevarthen & Aitken, 2001).  Gaze is also used by infants to

39 anticipate the actions of others; to regulate arousal in social interactions; to initiate joint

40 attention, and as a medium for making non-verbal requests (Crais et al., 2009; Stifter & Moyer,

41 1991). Furthermore, infant gaze provides caregivers with important information regarding

42 infant state and interest, particularly before they develop the capacity to communicate

43 intentionally (Coupe-O'Kane & Goldbart, 1998; Cronin & Mandich, 2015).

44

45 Studies have shown that gaze and the visual processing of food images are important indirect

46 indicators of hunger and satiation. These suggest that visual attention to food varies with

47 hunger and satiation, and between individuals of different weights.  Nijs et al. (2010) used eye

48 tracking and a visual probe task to examine attention to pictures of food during hunger and

49 satiation in overweight and normal weight adult females. They found no differences between

50 groups or conditions in the eye-tracking data. However, the visual probe task showed greater

51 automatic orientation by participants towards food cues in hungry versus satiated states, and

52 by overweight versus normal-weight participants.

53

54 Research suggests that gaze also provides a measure of interest in food in children. In a study

55 which controlled for hunger, Folkvord et al. (2015) investigated the impact of food advertising

56 on children's intake of snacks. They found that children who showed a longer gaze duration

57 for food cues in a digital advertising game, ate more of an advertised snack than those who

58 were not attentive to the cues.

59

60 Although evidence suggests that gaze and the visual processing of food cues may differ by

61 weight and hunger status in adults and children, gaze has received little attention as a marker

62 of infant feeding state in the research literature. A small body of research exists regarding

63 mothers' perceptions of hunger and satiation cues. Within this, mothers' reports tend to

64 describe feeding cues in terms of mouth behaviours (e.g. mouthing food); vocal behaviours

65 (crying or verbal requests) and bodily movements (reaching for food, pushing food away)

66 (Skinner et al., 1998; Hodges et al., 2008). This suggests that gaze is not perceived as

67 important by mothers in the signalling of hunger or satiation. However, there are some

68 indications that this aspect of behaviour is involved in the communication of infant feeding

69 state. Qualitative research by Anderson et al. (2001) concerning mothers' assessment of

70 infants' readiness for weaning, found infants' visual interest in others' food was one signal that

71 mothers used to determine their babies' readiness for the introduction of CF. Meanwhile,

72 mothers in the study by Hodges et al. (2008) identified 'staring' as a hunger cue. However,

73 this was cited 'infrequently' and no further detail on the behaviour was provided.

74

75 Gaze has also received some limited attention within a small number of observational studies

76 investigating behaviours associated with infant hunger and satiation under controlled

77 conditions. Like maternal report studies, these have tended to focus on motor movements

78 (hand movements) and mouth behaviours (sucking) during hunger and satiation, rather than

79 gaze (Lew & Butterworth, 1995; Turkewitz et al., 1966). However, Paul et al. (1996) examined

80 infant gaze in conditions of hunger and satiation, alongside movement and sucking

81 behaviours. They found significantly higher eye movement frequencies and longer durations

82 of visual exploration of objects before and after milk feeds in infants of 18 weeks of age and

83 older, compared with those during feeding. They did not find significant differences between

84 pre and post prandial gaze. The frequency of infant eye movements and the duration of visual

85 exploration therefore appear to be lower during feeding than outside of feeding.

86  While Paul et al (1996) did not detect differences between pre and post prandial gaze in milk

87  fed infants, one study has identified significant changes in gaze behaviour in hungry and full

88  infants. An experimental study by Gerrish and Menella (2000) examined the responsiveness

89  of 13 four to six-month-old infants to a rotating, musical mobile before and after breastfeeds

90  by examining frequency of limb movements and duration of gaze at the mobile when switched

91  on and off at one minute intervals on two separate days. The authors found no significant

92  differences in limb activity in pre and post prandial states. However, the infants looked at the

93  mobile significantly longer after breastfeeding than prior to breastfeeding, thereby suggesting

94  that gaze may serve as an indicator of infant feeding state in milk fed infants of the age tested

95  in the study.  Specifically, greater interest after feeding suggests a shift in attention towards

96  the mobile during the fed state.

97

98  Given indications that gaze differs with infant feeding state, and the key role that it plays in

99  infant communication, it seems likely that a systematic examination of this behaviour may

100  provide new insights into the signalling of infant hunger and satiation. The current lack of

101  studies in the area, however, means there are no tools for investigating gaze change during

102  infant feeding. There are brief references to infant gaze in some responsive feeding measures.

103  For example, gaze aversion is identified as a potent disengagement cue in the Nursing Child

104  Assessment Satellite Training (NCAST) Feeding Scale (Sumner & Spitz, 1994) and visual

105  attentiveness to the caregiver is regarded as an indicator of infant feeding responsiveness in

106  the Responsiveness to Child Feeding Cues Scale (Hodges et al., 2013). However, these

107  scales serve primarily as measures of caregiver feeding responsiveness, and they do not offer

108  a means of following or measuring infant gaze across meal episodes. The present study

109  therefore had three aims: (1) to develop a reliable coding scheme to track infant gaze across

110  mealtimes, (2) to test the feasibility of applying the coding scheme to mealtime gaze

111  behaviours, (3) to use the scheme to examine gaze behaviour change across an infant feeding

112  episode. A decision was taken to develop and test the scheme in the context of CF rather than

113  milk feeds, given infants' greater trunk and head stability beyond the age of six months; also,

114  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).

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

144         meal progressed.

145

## Participants

147 Flyers containing study information were sent to day nurseries and mother and baby groups

148 in Leeds, England and surrounding areas. Twenty mother-infant dyads were recruited. Infants

149 were eight males and twelve females between six and eighteen months old at the time of entry

150 into the study (mean age 11.7 months ± 3.40). Seven infants had been fed using baby led

151 weaning principles (BLW[1])( as defined by their mothers), One BLW mother reported

152 occasional use of a spoon to feed yoghurt and to start meals. The remaining four BLW mothers

153 reported using only independent feeding or use of a loaded spoon for the infant to self-feed.

154 Thirteen infants had been fed using traditional spoon feeding (SF) followed by more

155 independent feeding with increasing age. All infants had been breastfed at birth for at least a

156 few days. Mean breastfeeding duration was 24.89 weeks (± 15.96). Six mothers continued to

157 breastfeed at the time of the study. Mean weaning age was 22.2 weeks (± 1.85). Mothers

158 were aged between thirty and forty-three years of age (mean age 34.6 ± 3.23). Nine were first

159 time mothers and all but two had an undergraduate degree or higher educational qualification.

160 Mothers gave consent for their infants to participate in the study and ethical approval for the

161 research was granted by the School of Psychology Ethics Committee at the University of

162 Leeds reference: 14-0010.

163

## Method

165 The study had four phases; phase 1 involved filming two separate feeding episodes between

166 mothers and their infants; phase 2 involved development, piloting and revisions to the coding

167 framework along with piloting of the coding method (continuous or instantaneous coding). This

168 phase used   video recordings taken in phase 1 and video recordings taken from an earlier

169 research study. Phase 3 involved formal reliability testing using a sample of 20% of the footage

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

170   of videos from phase 1 along with final revisions of the coding scheme itself. Phase 4 involved

171   the coding of the entire video data set and related analyses.

172

173   ## Phase 1
174   ### Data collection
175   Participants were visited three times at home. At the first visit, demographic details and a

176   feeding history were taken. At visits two and three, infants were video recorded eating a

177   familiar meal at their usual lunchtime. The mean time between filming visits was sixteen days

178   (±12.80). Mothers were asked to not feed their babies for at least an hour before filming and

179   to avoid any substantial intake of food or drink before this to ensure that infants were hungry

180   before the meal. During filming mothers were asked to serve a familiar and liked meal in line

181   with normal feeding practice and to ignore the presence of the researcher. Most infants (n =

182   16) ate dessert as well as a main course at both filming visits and both courses of the meal

183   were filmed accordingly. Wherever possible, filming took place in the absence of siblings to

184   minimise interruptions to the meal. However, an older sibling was present during filming with

185   one family.

186

187   Meals were filmed using a Panasonic SDR-H90 video camera and filming commenced with

188   the seating of the infant in the high chair or at the table. The majority of mothers sat opposite

189   their infants during filming, with short periods of time away from the infant for food preparation,

190   clearing up dishes and general activities. One of the mothers did not sit with her infant during

191   the meal but interacted with the infant between bouts of food preparation. Filming ended when

192   mothers indicated that the meal was finished.

193

194   ## Phase 2
195   ### Development of codes
196     The initial development of the Infant Gaze at Mealtime (IGM) coding scheme was largely

197   informed by observations of a sample of five study videos and five other infant feeding videos

198  from an earlier project which were available to the first author. Observational codes were

199  developed largely as descriptions of gaze direction during the feeding episode e.g. 'gazes at

200  food, gazes at drink etc.' (Table 1).  The code 'gazes at other' was used to describe instances

201  of the infant gazing at non-feeding related items and the infant gazing at the camera. Infants

202  were also observed to gaze at the caregiver during feeding. The code 'gazes at caregiver' was

203  therefore also included to describe gaze direction and on the basis that visual attentiveness

204  to the caregiver appears as an indication of feeding responsiveness in the RCFCS (Hodges

205  et al., 2013).

206

| 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 | |

207

208  **Table 1 - First version of gaze codes**

209

210  Two further descriptions of infant gaze were also included in the initial coding scheme:

211  'watches caregiver' where the infant's gaze followed the caregiver's movements for example

212  around the kitchen (rather than gazing directly at the caregiver's face); and 'active gaze

213  aversion' where infants were observed to avert their gaze in direct response to offers of food.

214  The inclusion of this code was also informed by its identification as a disengagement cue in

215  the NCAST feeding scales (Sumner & Spitz, 1994). Finally, an 'unobservable' code was

216  included for instances where the infant's eyes were obscured, making the identification of

217  gaze direction/gaze behaviour impossible. Modifiers were included in the initial coding scheme

218  for gazing at the caregiver, gazing at food and gazing at other objects, to identify whether gaze

219  was directed to these spontaneously, or whether it was prompted, for example by the

220  caregiver drawing the infant's attention to an item or to herself. Descriptors were developed

221     alongside all behaviour codes to provide additional details for coders regarding the appropriate

222     use of codes.

223

224     Piloting of codes

225     The usability of the initial IGM was assessed by piloting codes individually with entire videos

226     from the first filming visit for five of the participants (89.23 minutes of footage in total). These

227     videos were observed to assess the feasibility of coding gaze and to ensure that codes

228     captured gaze behaviours comprehensively. Following this pilot, a number of changes were

229     made to the first version of the scheme (Table 2). First, the IGM was simplified by removing

230     the 'spontaneous or prompted' modifiers for 'gazes at caregiver', 'gazes at drink', ' gazes at

231     food' and ' gazes at other'. During piloting the vast majority of gaze shifts were observed to be

232     infant initiated, and the inclusion of modifiers therefore made coding unnecessarily time-

233     consuming. Furthermore, there were also occasions where the categories proved unworkable,

234     for example, it was difficult to categorise gaze shifts to the caregiver as being unequivocally

235     spontaneous or prompted if they were part of an ongoing social exchange.

236

| 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 |

237

238     **Table 2 – The revised coding scheme**

9

239  The second change involved the addition of a new code. Infants were observed to engage in

240  a type of gaze behaviour which was not yet captured by any code, whereby they would gaze

241  intently at objects such as feeding utensils, remaining pieces of food or objects such as empty

242  yoghurt pots, while actively manipulating them (e.g. turning, squeezing, etc.). The

243  developmental psychology literature indicates that such visual examination is associated with

244  exploratory play (Ruff & Salterelli, 1993) and a new code of 'exploratory gaze' was therefore

245  added.

246

247  ## Piloting of coding method

248  Following revision of the IGM, a second round of piloting was conducted to establish the most

249  feasible method for coding, i.e. whether to code continuously or to use instantaneous

250  sampling. The main observer (JM) and a second trained observer coded footage from the

251  main courses of five selected films from phase one on a continuous basis. Films were selected

252  in order to observe infants from a range of different ages between 6 and 14 months. The first,

253  middle and last twenty percent of main course footage was used. Fifteen video sections of

254  between 1.53 and 4.74 minutes length were coded with a total of 46 minutes of film coded.

255  The same observers then coded the same films using an instantaneous sampling frame of

256  three seconds, i.e. frozen images were coded every three seconds. Discussions of pilot coding

257  indicated that instantaneous sampling offered a more feasible coding method than continuous

258  sampling and therefore one which was more likely to be reliable. Instantaneous sampling

259  enabled coders to observe and interpret behaviours from relatively clear, frozen images every

260  three seconds. In contrast, coders encountered difficulty coding gaze shifts continuously, as

261  these were often subtle and fleeting. A decision was therefore taken to use the instantaneous

262  sampling method for coding. The test interval of three seconds was retained; this allowed for

263  frequent observation of infant gaze whilst reducing the risk of missing behaviours and

264  minimizing burden on coders.

265

## 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

296    process was repeated for the second half of the reliability film clips until all observations

297    achieved correlation coefficients of at least 0.70 for all video observations between the main

298    and second coders.

299

300    Pearson's correlations provide information about the strength of a relationship between two

301    sets of ratings rather than actual agreement between sets of ratings (Stolarova, Wolf, Rinker

302    and Brielmann, 2014). As such, while useful for coder training and feedback, they are not

303    considered the best option for final reliability analyses (Bakeman and Quera, 2011). Final

304    analyses were therefore conducted using two-way mixed effects, single measure intra-class

305    correlations (ICCs) for absolute agreement across all behaviour codes on all observations,

306    and absolute agreement on individual codes across all observations. The ICCs were carried

307    out using square root transformed data, as observational coding data were not normally

308    distributed (Hallgren, 2012).

309

310    Test-retest reliability analyses were also performed to assess the reliability of the IGM over

311    time. The same sample of 48 film clips was re-coded by the main coder 20 weeks after the

312    initial coding session. Again, two-way mixed effects intra-class correlations were conducted

313    with transformed data for absolute agreement. Analyses were carried out to examine total

314    agreement across all observations in the reliability sample at the first and second coding, and

315    for each of the individual gaze behaviour codes at the first and second coding.

316

317    Phase 4

318

319    The same procedure was followed for video analysis as for phase 3 with meal videos divided

320    into mains and desserts and further sub-divided into the first, middle and last twenty percent

321    of course footage.  225 video sections of between 26 and 355 seconds in length were coded

322    using Noldus Observer. As with phase 3, videos were coded in random order.

323

## 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.

351    Results

352

353    Inter-rater reliability

354    Intra-class correlations across all 48 observations were in the excellent range, ICC= .95 with

355    a 95% confidence interval from .95 to .96 (F (383,766) = 58.70 p < .001) (Cicchetti, 1994).

356    Intra-class correlations for individual gaze codes were good to excellent (Table 3).

357

| 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 |

358

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

360

361    Test-retest reliability

362    Test-retest intra-class correlations across all 48 observations were in the excellent range,

363    ICC= .97, with a 95% confidence interval from .97 to .98 (F (383,383) = 95.31 p < .001). Intra-

364    class correlations for individual gaze codes were all in the excellent range (Table 4).

365

366

| 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 | $F_{(47,47)} = 30.85$, $p < .001$ |

367

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

369 Whole meal descriptive statistics

370 Gazing at other showed the highest mean frequency across the six time points of the whole

371 meal (Table 5). This was also the most variable behaviour. Gazing at food showed the second

372 highest mean frequency whilst the lowest mean frequency was seen in active gaze aversion.

373

| 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 |

374

375
376 **Table 5 – Mean Gaze Frequencies Across Whole Meals**

377
378 Main course descriptive statistics

379
380 Mean frequencies of exploratory gaze and gazing at the caregiver increased at all three time

381 points during the main courses while those of gazing at food and watching the caregiver

15

382  decreased. There were no discernible patterns of change for other gaze behaviours across

383  time in the main courses.

384

385

386

387  Mean frequencies of gaze aversion from food, gazing at the caregiver, and gazing at other

388  increased over time in the dessert courses and gazing at food and ==watching the caregiver==

389  ==decreased.== No other patterns of gaze change were observed.

390

391  Time1 to Time 6 ANOVAs and Wilcoxon's Test

392  Repeated measures ANOVAs of gaze change between the hungriest and most satiated parts

393  of the meal (the first and last 20%) revealed highly significant decreases over time in the

394  frequency of Gazing at Food, $F_{(1,15)} = 23.14$, $p < .001$, $\eta p^2 = .61$  and Gazing at Other, F

395  $_{(1,15)} = 10.22$, $p = .001$, $\eta p^2 = .41$  and a significant increase in time in the frequency of

396  exploratory gaze, $F_{(1,15)} = 5.14$, $p = .039$, $\eta p^2 = .26$. Wilcoxon's signed ranks tests also

397  revealed a highly significant median decrease in watching the caregiver, $Z = -3.02$, $p = .001$.

398  No other significant changes in gaze behaviour were observed between Times 1 and 6.

399

400  Whole Meal ANOVAs

401  Three-way repeated measures ANOVAs revealed a highly significant main effect for course,

402  $F_{(1,15)} = 26.42$, $p < .001$, $\eta p^2 = .64$, indicating that gaze behaviours as a whole differed

403  between main and dessert courses. A highly significant main effect was also shown for

404  behaviour, $F_{(6,90)} = 59.43$, $p < .001$, $\eta p^2 = .80$ thereby indicating that different types of gaze

405  behaved differently during meals, i.e. the independence of different behaviours. Highly

406  significant interactions were also found for course by behaviour, $F_{(6,90)} = 3.62$, $p = .003$, $\eta p^2$

407  $= .19$ and behaviour by time (after the application of the Greenhouse Geisser correction), F

408  $_{(6.13,91.98)} = 12.19$, $p < .001$, $\eta p^2 = .45$. As such, overall gaze behaviour was seen to vary

409  both by course and by time.

410

16

411      Whole meal ANOVAs of individual types of gaze by course found significantly higher

412      frequencies of a number of gaze behaviours in main than dessert courses, i.e. gazing at food:

413      $F_{(1,15)} = 5.41$, p = .034, $\eta p^2$ = .27; gazing at the caregiver: $F_{(1,15)} = 10.22$, p = .006, $\eta p^2$

414      = .41; gazing at other: $F_{(1,15)} = 22.31$, p < .001, $\eta p^2$ = .60 and watching the caregiver: F

415      $_{(1,15)} = 5.14$, p = .039, $\eta p^2$ = .26.

416

417      Main Course ANOVAs and Friedman's tests

418      A significant main effect for gaze was found $F_{(6, 114)} = 49.45$, p < .001, $\eta p^2$ = .72 indicating

419      that different forms of gaze behaved differently during the main courses of meal. Mauchly's

420      test was significant for the interaction between gaze and time. This was found to be significant

421      on the application of the Greenhouse-Geisser correction, $F_{(12, 100.60)} = 8.31$, p < .001, $\eta p^2$

422      = .30 showing that gaze frequency changed with time for some types of gaze behaviour.

423

424      Repeated measures ANOVAs did not show significant results for gazes at caregiver and

425      gazes at other. However, a highly significant result was found for Gazes at food $F_{(2,38)}$ =

426      8.572, p = .001, $\eta p^2$ = .31, with a significant decrease in the frequency of this behaviour over

427      time (Figure 1).

428
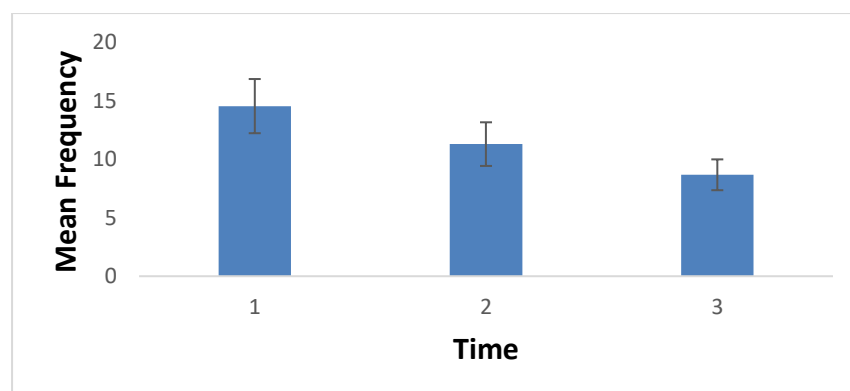
429



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

431

432    Pairwise comparisons indicated that significant differences in gazing at food occurred between

433    time 1 and time 2 (p = .029) and time 1 and time 3 (p = .002). No significant difference was

434    observed between times 2 and 3.

435

436    Friedman's tests revealed a significant increase in the frequency of exploratory gaze over

437    time, $X^2$ (2) = 18.47, p < .001 (Figure 2). Post hoc Wilcoxon signed-rank tests found a

438    significant increase over time for exploratory gaze behaviour between times 1 and 2, Z = -

439    3.53, p < .001 and times 1 and 3, Z = -3.38, p < .001, but not between time 2 and time 3.

440    Therefore, infants' interest in exploring increased by the second half of the meal and remained

441    high relative to the beginning of the course.

442
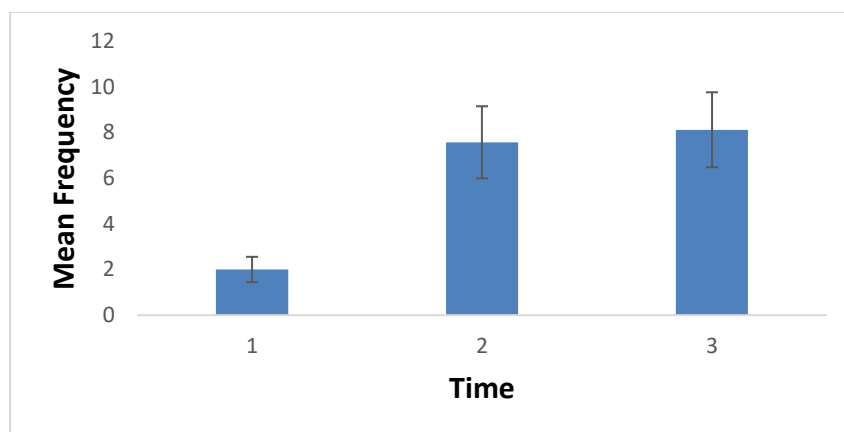


443

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

445

446    A highly significant median decrease was also observed in the frequency of watching the

447    caregiver over time, $X^2$ (2) = 9.51, p = .007 (Figure 3). Wilcoxon signed-rank tests showed

448    significant decreases in the frequency of this behaviour between times 1 and 2 (Z = -2.36, p

449    = .008) and 1 and 3, Z = -2.63, p = .003**.** Thus, infants' gaze shifted from watching their

450    mothers as main courses progressed. Friedman's analyses did not reveal any significant

451    changes over time in active gaze aversion or gazing at other.

452
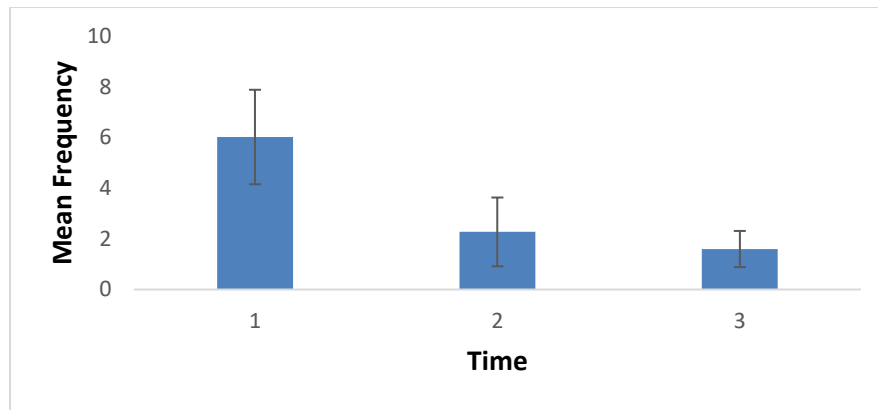
453

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

455

456 Dessert course ANOVAs and Friedman's tests

457

458 A significant main effect for gaze was found $F_{(6, 90)} = 5.74$, $p < .001$, $\eta p^2 = .28$ . There was

459 also a significant main effect of time, $F_{(2,30)} = 48.46$, $p < .001$ , $\eta p^2 = .76$  and a significant

460 interaction between gaze and time following application of the Greenhouse-Geisser

461 correction, $F_{(12, 80.77)} = 33.50$, $p < .001$ , $\eta p^2 = .69$ .

462

463 In contrast to the main courses, repeated measures ANOVAs showed a significant increase

464 over time in the frequency of gazing at the caregiver during desserts, $F_{(2,30)} = 8.27$, $p = .001$,

465 $\eta p^2 = .36$ (Figure 5). Pairwise comparisons revealed that significant changes in the frequency

466 of gazing at the caregiver occurred between times 1 and 3 ($p = .005$) and 2 and 3 ($p = .049$).

467 Significant decreases were also observed in the frequency of gazing at food $F_{(2,30)} = 16.84$,

468 $p < .001$, $\eta p^2 = .53$ (Figure 6) with pairwise analyses identifying that these occurred between

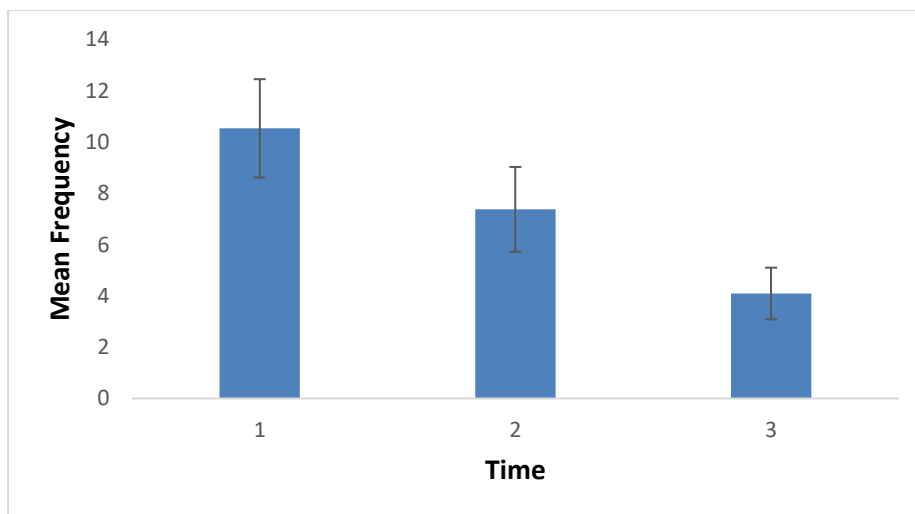469 times 1 and 3, and 2 and 3 ($p < .001$ and $p = .011$).

470

471

472
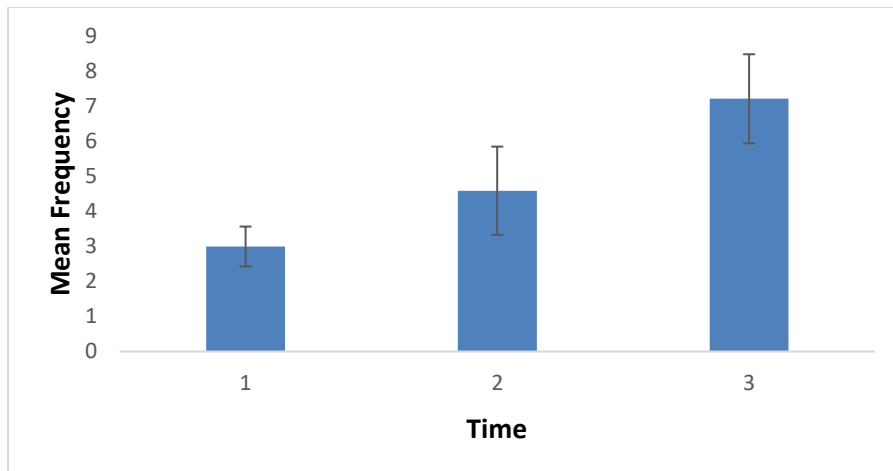
**Figure 4 – Dessert Course Gazing at the Caregiver Mean Frequencies and Standard**
**Errors**

475



476

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

478
479
480

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).

486
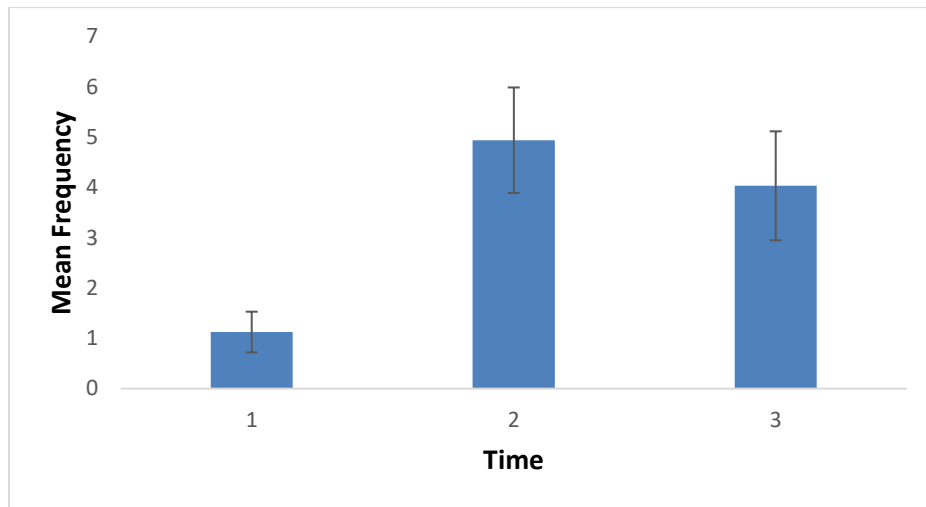


487

488

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

490 ## Discussion

491 This study aimed to develop and test a reliable coding system to examine infant gaze during

492 CF. Results indicate that the scheme (the IGM) is a reliable measure and that observation of

493 infant gaze during meals may provide insights into hunger and satiation levels. This is

494 predicated on the assumption that gaze behaviour observed at the start of an eating episode

495 is likely to be associated with hunger, while that observed later is likely to associated with

496 satiation.

497

498 ### Reliability of the IGM

499 High inter- and intra-rater reliabilities were found for the IGM. These can be attributed to its

500 comprehensiveness and simplicity in describing the orientation of infant gaze. Results are

501 consistent with findings from earlier studies indicating that adult and infant gaze can be coded

502 with high levels of reliability, (Harrigan, Rosenthal & Scherer, 2008; Ruff, Capozzoli &

503 Saltarelli, 1996). The high reliability of the coding scheme is likely to arise to some degree

504 from the conditions in which it was tested. First, the use of video coding software and

505 instantaneous sampling facilitated the observation of relatively clear, 'frozen' images, thereby

506 increasing coding accuracy. Second, the use of video software enabled the slowing down and

507  repeated viewing of behaviours. Furthermore, the practice of reviewing inter-rater agreement

508  half way through reliability coding is likely to have reduced coder drift (Martin, Bateson &

509  Bateson, 2007).

510

511  Despite high levels of inter-rater reliability for individual behaviours, the ICC for 'unobservable'

512  gaze was low relative to other behaviours, (in the good rather than the excellent range). The

513  descriptor for this code may therefore benefit from refinement. Coders were instructed to use

514  this code if both of the infant's eyes were obscured, or the direction of gaze could not be

515  discerned. Images of infants' eyes were sometimes indistinct in video stills however, leading

516  to disagreement between coders.

517

518  Testing and subsequent revisions of the IGM generated a scheme which described all gaze

519  behaviours during feeding adequately. In addition, its development from naturalistic

520  observations is also likely to ensure good external validity (Knapp et al., 2013). Despite this,

521  there are potential threats to validity of the scheme, e.g. the removal of the 'spontaneous' and

522  'prompted' gaze modifiers during scheme development means it will have inevitably captured

523  gaze shifts prompted by mothers rather than entirely infant initiated ones. The context in which

524  videos were recorded may also have affected coding accuracy, e.g. there were times when

525  the direction of infant gaze could not be ascertained as this was directed at items which were

526  out of shot. Participant reactivity to the presence of the camera may also mean the frequency

527  of some behaviours was over or under-estimated. This point made, infants appeared to be

528  more accustomed to the camera at the second filming visit.  This may have helped to mitigate

529  reactivity.

530

531  Additional limitations to the scheme arise from the use of instantaneous sampling rather than

532  continuous coding. This may have limited the IGM's accuracy in assessing the frequency of

533  gaze behaviours meaning the rates and durations of different gaze behaviours could not be

534    calculated (Martin & Bateson, 2007) and data could not be used for sequential analysis

535    (Bakeman & Gottman, 1997).

536

537    Gaze change across eating episodes

538    Significant decreases were observed between the times at which we assumed the infant was

539    hungriest and most satiated for gazing at other, watching the caregiver and gazing at food

540    while a significant increase was noted for exploratory gaze (i.e. instances of infants gazing

541    intently at feeding utensils, food remnants etc.) while physically manipulating them). Such

542    behavioural changes may therefore be indicative of infant feeding state. However, only gazing

543    at food and exploratory gazing showed consistent changes over time at course as well as

544    meal level. Watching the caregiver showed a significant reduction over time in main courses

545    but not desserts. This may be explained by the observation that mothers spent more time

546    preparing food at the start of mains than desserts, with the latter largely involving pre-

547    prepared/quickly prepared foods such as fruit or yoghurt. This provides further support for

548    watching the caregiver as an indication of hunger and some support for hypothesis 1 as it

549    represents a move away from feeding related to non-feeding related gaze over time. However,

550    it should be noted that decreases in the frequency of this behaviour were not independent of

551    mothers' actions; mothers tended to stop food preparation early in the meal/main course and

552    then sat down, meaning there was less for infants to 'watch' as time progressed. In addition,

553    it is unclear whether infants watched their mothers early in the main course because they were

554    preparing food or out of general curiosity.

555

556    The significant reduction in gazing at other from time 1 to time 6 and the significantly lower

557    frequency of this behaviour during dessert than main courses should also be interpreted

558    cautiously. This behaviour may be indicative of hunger as, during filming, infants appeared to

559    engage in 'looking round' early in the meal while absorbed in eating. However, no significant

560    reduction was observed over time in this behaviour within main or dessert courses.

561    Furthermore, as looks to the camera were coded as gazes at other, it is possible that

562    decreases in this behaviour may have occurred in part as a result of infants becoming less

563    interested in the camera over time.

564

565    Findings for gazing at food and exploratory gaze in meals as a whole and during separate

566    courses both provide support for hypothesis 1 and hypothesis 2, i.e. the prediction that infants

567    would look less at food and would engage more in non-food related gazing over time and that

568    more hunger related gazing would be observed in the earlier stages of the meal (i.e. the main

569    course). Findings regarding   exploratory gaze also provide support for hypothesis 1, and the

570    increase in this behaviour as main and dessert courses progressed is consistent with Gerrish

571    and Menella's (2000) finding that infants showed greater visual attention to a mobile after,

572    rather than before, breastfeeding, and, with parental reports of infants playing with their food

573    as a satiation sign (Hodges et al., 2008; Hodges et al., 2016; Skinner et al., 1996). Importantly,

574    changes in this behaviour and gazing at food also provide support for hypothesis 3 that similar

575    patterns of gaze change would be seen between main and dessert courses as a result of

576    sensory specific satiety (Rolls et al., 1981).  Exploratory gaze increased over main courses

577    but decreased at the beginning of desserts before resuming a generally upward trend.

578    Similarly, decreases in gazing at food were progressive within courses but not from one course

579    to the next, i.e. this behaviour decreased over time in the main courses but increased in

580    frequency at the beginning of desserts before declining again.

581

582    Findings regarding the timing of changes to the frequency of gazing at food and exploratory

583    gaze also have implications for understanding their status as markers of infant satiation.  In

584    both main and dessert courses a significant increase was observed in the frequency of

585    exploratory gaze by the middle 20% of the course, suggesting changes in this behaviour

586    indicate developing (rather than complete) satiation.  Similarly, a significant decrease in the

587    frequency of gazing at food was observed by the middle 20% of main courses. The same

588    pattern was not observed for decreases in gazing at food during desserts. In these the

589    significant decrease occurred between the middle point of the courses and the end. This may

590    reflect differences in the presentation of food between main and dessert courses; many

591    mothers in the study offered fruit as dessert, i.e. by giving a few berries at a time, rather than

592    providing a 'full dessert portion' in one go. Alternatively, the later change in the frequency of

593    gazing at foods between main and dessert courses may reflect an infant interest in dessert

594    (sweet foods) which persists for longer than for savoury foods.

595

596    Findings for gazing at the caregiver were mixed. The higher frequency of this behaviour during

597    main than dessert courses might suggest that it is associated with hunger. This would be

598    consistent with TW infants using eye contact to indicate readiness for the next spoonful of

599    food (Crais et al., 2009; Stifter & Moyer, 1991), thereby supporting hypothesis 2. However, a

600    significant increase over time was observed in the frequency of gazing at the caregiver during

601    desserts but not main courses. This would suggest this behaviour is associated with satiation

602    and a move away from feeding related to social gaze during desserts thereby contradicting

603    hypothesis 2. The most likely explanation for these contradictory findings is that infants use

604    dyadic gaze for different communicative aims (requesting and social interaction) and so this

605    behaviour may be used to signal both hunger and satiation.

606    Hypothesis 4 was not supported by this study as no significant reductions were observed in

607    active gaze aversion either between Times 1 and 6 of the whole meal, or in separate main or

608    dessert courses. This is unexpected given that gaze aversion has been identified as a potent

609    indication of satiation in infants (Hodges, 2008; Sumner & Spietz, 1994). One would therefore

610    expect to see this behaviour increase over time. However, the likelihood of observing gaze

611    aversion is dependent on maternal responsiveness. It may be that mothers in this sample

612    were relatively responsive to infant fullness thereby obviating the need for infants to display

613    this 'strong' satiation cue. This is supported by sample characteristics – most mothers were

614    well educated with relatively long histories of breastfeeding. Such characteristics are known

615    to be associated with greater feeding responsiveness (Hodges et al. 2013). Furthermore, a

616    third of infants in the sample were fed using BLW, while another third were feeding with some

617    degree of independence, again decreasing the likelihood of observing gaze aversion.

618

## 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.

26

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