Abstract

Behaviors observable during the eating in the absence of hunger (EAH) protocol may be useful early indicators of an emerging avid eating phenotype, but have not been examined in infancy. This study videotaped infants being offered desserts (e.g., cakes, donuts) after a meal, measured intake, and coded observed behaviors (variety, eating duration, rate, latency, and engagement, bite size, positive affect before and after tasting, latency to negative affect, and negative affect and resistance when dessert was taken away), which were scored to generate a 12-point eating avidity index (EAI). Sociodemographics, eating behaviors (Children's Eating Behavior Questionnaire-Toddler (CEBQ-T) subscales and food-related tantrums), and dietary sweets intake were reported and anthropometrics measured. Multiple linear regression was used to predict intake and EAI from covariates. Infants (n=118) ate *M*=86.6kcals in *M*=5.55min after a latency of *M*=0.63min; 28% displayed positive affect before tasting and 73% after, and 13% displayed negative affect when dessert was taken away. Intake was positively associated with variety, eating duration, rate, and engagement, and bite size. Intake and avidity for eating dessert were predicted by CEBQ-T enjoyment of food and dietary sweets intake, but not by sociodemographics or adiposity. Intake was predicted by food-related tantrums. During the EAH protocol, many infants demonstrated multiple behaviors reflecting an eating style high in food approach, and many of these behaviors, with the exception of affect, correlated with intake and one another and may reflect an emerging avid eating phenotype. Identifying the etiology and moderators of this avid eating phenotype would inform prevention efforts.

Keywords: infant, eating behavior, feeding behavior

Click here to access/download;Figure;Figure_1_Participant Flow diagram 9-26-25_clean.docx

Figure 1. Participant flow diagram

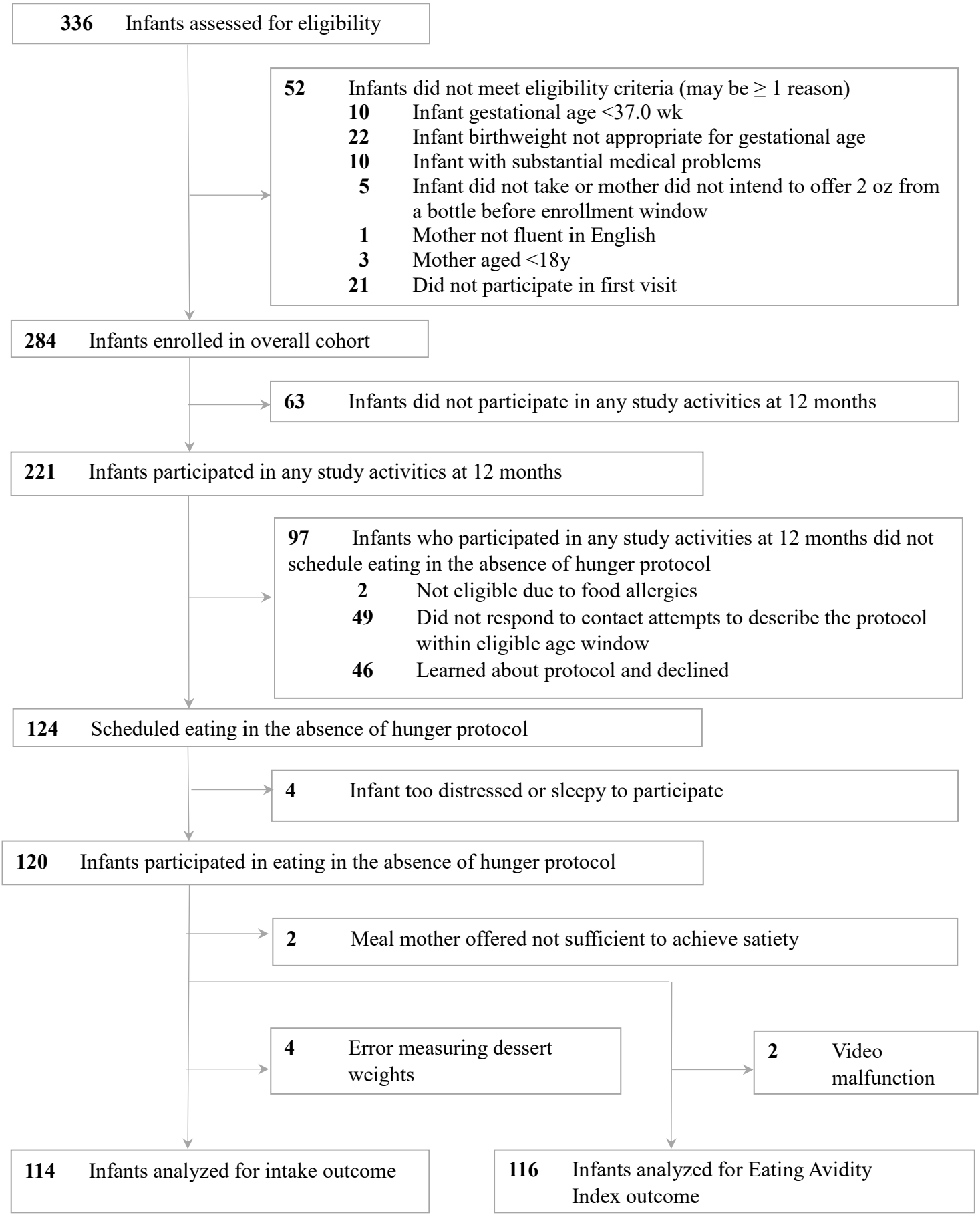


Table (Editable version) Click here to access/download;Table (Editable version);Tables 1-3_9-23-25_2pm_clean.docx

Table 1. Desserts Offered

	Weight (grams)	Kilocalories[a]	Kilocalories per gram	Percent of cohort taking at least one bite	
Hostess™ Chocolate Cupcake	45.0	160	3.56	Yes	98 (84%)
				No	18 (16%)
Hostess™ Orange Cupcake[b]	48.0	180	3.75	Yes	77 (68%)
				No	36 (32%)
Entenmann's™ Party Cakes Little Bites	11.75	47.5	4.04	Yes	88 (76%)
				No	28 (24%)
Little Debbie™ Powdered Donut	13.25	57.5	4.34	Yes	89 (77%)
				No	27 (23%)
Little Debbie™ Red Velvet Cake[c]	36.5	165	4.52	Yes	35 (60%)
				No	23 (40%)
Little Debbie™ Zebra Cake[d]	37.0	160	4.32	Yes	31 (53%)
				No	27 (47%)

[a] Based on data on packaging
[b] Not offered to three participants due to supplier shortage
[c] Offered to first 56 participants until supplier stopped production.
[d] Offered to latter 60 participants after supplier stopped production of Red Velvet Cake.

Table 2. Sample Characteristics

Characteristic	No. (%)
No. of infants	118
Infant sex	
Male	64 (54)
Female	54 (46)
Infant age, mean (SD), months	12.4 (0.5)
Infant race/ethnicity	
White, non-Hispanic	80 (68)
Black, non-Hispanic	11 (9)
Hispanic, any race	7 (6)
Other, non-Hispanic	19 (16)
Missing	1 (<1)
Infant gestational age, mean (SD), weeks	39.5 (1.1)
Infant birthweight, mean (SD), kilograms	3.4 (0.4)
Infant weight-for-age z-score, mean (SD)	0.1 (1.0)
Infant length-for-age z-score, mean (SD)	-0.4 (1.1)
Infant weight-for-length z-score, mean (SD)	0.4 (0.9)
Maternal age, mean (SD), years	32.2 (4.8)
Maternal education	
<4 years of college	30 (25%)
4 years of college	40 (34)
> 4 years of college	48 (41)
Maternal body mass index, mean (SD), kg/m^2	28.0 (8.1)
Confusion, Hubbub And Order Scale total score, mean (SD)	3.0 (3.2)
Infant Children's Eating Behavior Questionnaire-Toddler, mean (SD)	
Satiety responsiveness	2.7 (0.6)
Enjoyment of food	4.2 (0.6)
Food responsiveness	2.5 (0.8)
Food fussiness	2.1 (0.6)
Emotional overeating	1.8 (0.7)
Infant food-related tantrums in last month	
Rarely asks for food	18 (17)
Asks for food and is rarely denied	50 (49)
Asks for food, rarely tantrums when denied	11 (11)
Asks for food and often tantrums when denied	24 (23)
Infant fed any sweet foods in last 7 days	
Yes	68 (63)
No	40 (37)

Table 3. Bivariate Associations[a] Among 12 Contributors to Eating Avidity Index																
				Mean (SD)	Median (IQR)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Intake (kcal)			1	86.6 (65.8)	68.3 (46.5, 115.4)	-										
Variety (# desserts)			2	3.6 (1.4)	4 (3, 5)	.48***	-									
Eating	Duration (min)		3	5.55 (1.67)	6.17 (4.67, 6.67)	.48***	.54***	-								
	Rate (kcal/min)		4	15.6 (11.4)	13.2 (9, 21.6)	.77***	.25**	-.04	-							
	Latency (min)		5	0.63 (1.06)	0.33 (0.17, 0.50)	-.28**	-.48***	-.35***	-.22*	-						
	Engagement (%)		6	38.3 (17.9)	38.5 (27.2, 51.1)	.67***	.59***	.66***	.39***	-.38***	-					
Bite size (kcal/min)			7	28.8 (17.4)	25.8 (15.6, 38.4)	.67***	.27**	.05	.79***	-.23*	.09	-				
Positive affect	Before tasting[b]	Yes	8	33 (28%)		-.11	.06	-.18	-.11	.05	-.11	-.09	-			
		No		83 (72%)												
	After tasting[b]	Yes	9	85 (73%)		-.10	.13	-.05	-.13	-.05	-.13	-.03	.34***	-		
		No		31 (27%)												
Latency to negative affect (min)			10	5.20 (2.93)	6.33 (2.17, 7.83)	.17	.09	.21*	.07	-.07	.08	.15	.07	.15	-	
Reaction to dessert being taken away	Negative affect[b]	Yes	11	13 (11%)		.00	-0.05	-.19*	.05	.00	.02	-.03	.02	-.03	-.28**	-
		No		103 (89%)												
	Resistance (# types)		12	0.5 (0.8)	0 (0, 1)	.26**	.23*	.21*	.15	-.01	.28**	.14	.00	-.07	.18*	.01

[a]Correlation (Pearson, Spearman, or phi coefficient, as appropriate); *p<.05, **p<.01, ***p<.001
[b]Dummy coded (yes=1, no=0); descriptives shown as n (%)

Table 4. Characteristics Associated with Outcomes in Unadjusted and Adjusted Analyses

	Intake (kcals)			Eating Avidity Index		
	Unadjusted	**Fully Adjusted**	**Final Adjusted**	**Unadjusted**	**Fully Adjusted**	**Final Adjusted**
	β (SE)	β (SE)	β (SE)	β (SE)	β (SE)	β (SE)
No. of infants	114	104	106	116	107	107
Infant sex (male vs. female)	0.66 (0.69)	-	-	0.13 (0.46)	-	-
Maternal age (years)	0.12 (0.07)	-	-	0.03 (0.05)	-	-
Maternal education (< vs. ≥4y college)	0.21 (0.80)	-	-	-0.18 (0.53)	-	-
Confusion, Hubbub And Order Scale total score	0.20 (0.11)	-	-	0.12 (0.07)	-	-
Infant birthweight (kg)	1.35 (0.81)	-	-	1.02 (0.56)	-	-
Infant weight-for-age z-score	0.23 (0.36)	-	-	-0.13 (0.23)	-	-
Maternal body mass index (kg/m^2)	0.07 (0.04)	-	-	0.01 (0.03)	-	-
Children's Eating Behavior Questionnaire-Toddler subscales						
Satiety responsiveness	-1.30 (0.61)*	-0.34 (0.78)	-	-0.61 (0.43)	-	-
Enjoyment of food	1.89 (0.58)**	1.21 (0.86)	1.30 (0.58)*	0.91 (0.41)*	0.82 (0.41)*	0.82 (0.41)*
Food responsiveness	0.86 (0.41)*	0.08 (0.48)	-	0.29 (0.28)	-	-
Food fussiness	-1.24 (0.60)*	-0.15 (0.64)	-	-0.53 (0.40)	-	-
Emotional overeating	0.49 (0.50)	-	-	0.15 (0.34)	-	-
Infant tantrums for food in last month (yes vs. no)	2.24 (0.80)**	1.61 (0.81)*	1.63 (0.77)*	0.67 (0.56)	-	-
Infant dietary sweets in last week (yes vs. no)	2.12 (0.71)**	1.78 (0.71)*	1.88 (0.68)**	1.11 (0.48)*	1.08 (0.49)*	1.08 (0.49)*

*p<.05, **p<.01; "-" indicates variable not tested in fully adjusted model because not associated in unadjusted models or not included in final adjusted model because not associated with outcome after removing one-by-one from fully adjusted model starting with the variable with the highest p-value.

Click here to access/download
Supplementary Material
Supplemental Tables 1-2_9-23-25_2pm_clean.docx

REVISED Manuscript (Clean copy)

Click here to access/download;REVISED Manuscript (Clean copy);Infant_EAH_9-26-25_12noon_clean.docx

Click here to view linked References

Predictors and Correlates of Eating in the Absence of Hunger at Age 12 Months

Katharine Asta, MD[a], Julie M. Sturza, MPH[a], Niko Kaciroti, PhD[a], Katherine L. Rosenblum, PhD[b], Ashley N. Gearhardt, PhD[c], Alison L. Miller, PhD[d], Hurley Riley, MPH[d], Julie C. Lumeng, MD[a, e]

Affiliations:

[a]Department of Pediatrics, University of Michigan Medical School, 2800 Plymouth Road, Building 520, Ann Arbor, Michigan

[b]Department of Psychiatry, University of Michigan Medical School, 4250 Plymouth Road, Ann Arbor, Michigan

[c]Department of Psychology, University of Michigan Ann Arbor College of Literature, Science, & the Arts, 2268 East Hall, Ann Arbor, Michigan

[d]Department of Health Behavior and Health Equity, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, Michigan

[e]Department of Nutritional Sciences, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, Michigan

Address correspondence to: Julie Lumeng, MD, Division of Developmental and Behavioral Pediatrics, 2800 Plymouth Road, Building 520, University of Michigan, Ann Arbor, Michigan, 48109; jlumeng@umich.edu

Data Statement: Data are available at https://deepblue.lib.umich.edu/data.

Abstract

Behaviors observable during the eating in the absence of hunger (EAH) protocol may be useful early indicators of an emerging avid eating phenotype, but have not been examined in infancy. This study videotaped infants being offered desserts (e.g., cakes, donuts) after a meal, measured intake, and coded observed behaviors (variety, eating duration, rate, latency, and engagement, bite size, positive affect before and after tasting, latency to negative affect, and negative affect and resistance when dessert was taken away), which were scored to generate a 12-point eating avidity index (EAI). Sociodemographics, eating behaviors (Children's Eating Behavior Questionnaire-Toddler (CEBQ-T) subscales and food-related tantrums), and dietary sweets intake were reported and anthropometrics measured. Multiple linear regression was used to predict intake and EAI from covariates. Infants (n=118) ate *M*=86.6kcals in *M*=5.55min after a latency of *M*=0.63min; 28% displayed positive affect before tasting and 73% after, and 13% displayed negative affect when dessert was taken away. Intake was positively associated with variety, eating duration, rate, and engagement, and bite size. Intake and avidity for eating dessert were predicted by CEBQ-T enjoyment of food and dietary sweets intake, but not by sociodemographics or adiposity. Intake was predicted by food-related tantrums. During the EAH protocol, many infants demonstrated multiple behaviors reflecting an eating style high in food approach, and many of these behaviors, with the exception of affect, correlated with intake and one another and may reflect an emerging avid eating phenotype. Identifying the etiology and moderators of this avid eating phenotype would inform prevention efforts.

Keywords: infant, eating behavior, feeding behavior

1. Introduction

Eating past satiation when presented with palatable foods predicts excessive weight gain in children (Lansigan, Emond, & Gilbert-Diamond, 2015; Savard, Bégin, & Gingras, 2022) and has therefore been the focus of substantial study since experimental measurement of eating in the absence of hunger (EAH) was first described more than 20 years ago (Fisher & Birch, 1999). EAH seems to increase from about ages three to twelve years (Lansigan et al., 2015; Savard et al., 2022) and is difficult to reverse once established (Savard et al., 2022), making prevention a priority. Prevention requires understanding how EAH develops. While many studies have described EAH at preschool-age (Lansigan et al., 2015; Savard et al., 2022), we identified only three studies occurring after the dietary transition to solid foods but before age three years, and none included infants younger than 18 months (Asta et al., 2016; Corsini, Kettler, Danthiir, & Wilson, 2018; Schultink et al., 2021).

1.1 Behavioral Displays of Eating Avidity During Eating in the Absence of Hunger

Energy intake is the classic outcome of the EAH protocol (Lansigan et al., 2015; Savard et al., 2022). Behavioral displays during the EAH protocol have received almost no research attention but may be a rich source of data, particularly among pre-verbal children. Fine- and oral-motor skills do not constrain many observable behaviors as they do intake (Remijn et al., 2019). Eating behaviors reflecting a larger, more avid appetite and a greater interest in food are typically defined as “high food approach” and are consistently positively associated with adiposity (Kininmonth et al., 2021). Behavioral displays that are, in particular, reflective of an eating style high in food approach (hereafter, “eating avidity”) may be a more sensitive risk indicator for future overeating than intake. Intrameal behavioral displays of eating avidity may also provide an opportunity for timely intervention that intake measurement at the meal’s conclusion does not.

Despite their potential value, we identified only one report evaluating behavioral displays during EAH, and it focused only on affect (Asta et al., 2016). Further, we could not identify any reports describing how behaviors exhibited during EAH associate with intake or with one another.

Behavioral displays during the EAH protocol may reflect an eating avidity phenotype. Specifically, the microstructure of eating (e.g., bite size, eating rate) has been the subject of decades of research (Davis, 1989; Guss & Kissileff, 2000), including among children (Pearce, Cevallos, Romano, Daoud, & Keller, 2022), but has not been examined during EAH. Just as a vigorous sucking style can be characterized by microstructural features of sucking (e.g., suck amplitude, frequency, or duration) during infancy (Feldman et al., 2023), and has predictive value for future eating behaviors reflective of high food approach (Feldman et al., 2023) and adiposity (Agras, Hammer, McNicholas, & Kraemer, 2004; Feldman et al., 2023; Stunkard, Berkowitz, Schoeller, Maislin, & Stallings, 2004), microstructural features of eating solids in infancy may also reflect an eating avidity phenotype. Similarly, consistent affective facial responses (e.g., smiling) to sweet taste across primates, including human infants within hours of birth, have been recognized for more than 50 years (Steiner, 1974; Steiner, Glaser, Hawilo, & Berridge, 2001) and the predictive value of displays of negative affect when very young children are denied desired food has been of interest to researchers studying excessive weight gain since the early 2000's (Agras et al., 2004).

Overall, following a proliferation of research since the 1990's on how specific appetitive traits are predictive of obesity risk in children, in the last several years, a number of researchers, in order to reduce the risk of a type 1 error, have sought to determine how eating behaviors may cluster. The several recent studies using latent profile analysis to develop holistic eating profiles have typically identified styles ranging from high to low food approach (Fisher et al., 2022;

Mattsson et al., 2021; Pickard et al., 2023). Determining whether eating behaviors observable during the EAH protocol can be collapsed into an index reflective of high food approach would have similar value with regard to reducing the risk of a type 1 error when testing correlates and predictors of the hypothesized avid eating phenotype indicated by these behaviors.

1.1.1 Microstructural Features of Eating Suggestive of Eating Avidity

Several behaviors observable during the EAH protocol may be more salient indicators of an avid eating phenotype than intake alone. For example, given that dietary variety positively associates with intake (Embling et al., 2021), adiposity (Fernandez, Kasper, Miller, Lumeng, & Peterson, 2016), and parent-reported enjoyment of food (Vilela, Hetherington, Oliveira, & Lopes, 2018), the number of different EAH foods tasted may be relevant. Continuing to eat the EAH food for a longer period of time may be important, given that eating duration positively associates with adiposity (Klesges et al., 1983). To our knowledge, no prior study has evaluated the rate at which the foods are consumed during the EAH protocol, which is surprising given that eating rate positively associates with intake (Fogel et al., 2017) and adiposity (Fogel et al., 2017; Garcidueñas-Fimbres, Paz-Graniel, Nishi, Salas-Salvadó, & Babio, 2021; Llewellyn, van Jaarsveld, Boniface, Carnell, & Wardle, 2008; Ohkuma et al., 2015). One might hypothesize that the speed with which a child begins eating the EAH foods would be important, given that more rewarding stimuli are approached more quickly (Field & Cox, 2008) and latency to begin eating negatively associates with intake (van den Akker, Bongers, Hanssen, & Jansen, 2017), desire to eat (van den Akker et al., 2017), and familiarity with (Addessi, Galloway, Visalberghi, & Birch, 2005) and liking for (Fernandez et al., 2016) the food stimulus, and positively associates with parent-reported food fussiness (Fernandez et al., 2016).

The extent to which the child attends to and engages with the EAH foods while they are available may vary significantly between individuals. Given that more rewarding stimuli draw more attention (Gearhardt, 2018), and attention to food and proportion of time engaging with food at mealtime positively associate with intake (Tan, Walczak, Roach, Lumeng, & Miller, 2018) and adiposity (Hendrikse et al., 2015), we would hypothesize that the proportion of time that the infant spends engaging with the food when it is available may be relevant. Finally, more voracious eating is often conceptualized as including a large bite size, given that bite size positively associates with intake and adiposity (Fogel et al., 2017).

1.1.2 Affective Responses Suggestive of Eating Avidity

Few studies have examined affective response to food cues in childhood (Asta et al., 2016; Laureati, Pagliarini, Toschi, & Monteleone, 2015; Miller, Rosenblum, Retzloff, & Lumeng, 2016). One might hypothesize that an infant exhibiting positive affect or "delight" upon being presented palatable foods may be an important behavioral marker for an avid eating phenotype, given that more rewarding stimuli are anticipated with more positive affect (Gearhardt, 2018), which for food positively associates with adiposity (Hendrikse et al., 2015). Surprisingly, however, among school-age children, positive affective response to food has limited correlation with intake (De Wijk, Kooijman, Verhoeven, Holthuysen, & De Graaf, 2012; Zeinstra, Koelen, Colindres, Kok, & De Graaf, 2009). Positive affect after the infant has started eating may be a salient marker of individual differences in the reward value of sweet food, given that sweet taste elicits positive affect (Gearhardt, 2018; Steiner et al., 2001), which positively associates with intake (Forestell & Mennella, 2007; Maneschy et al., 2024) and adiposity (Kininmonth et al., 2021).

Negative affect may also be an important behavioral response to capture as a correlate (either positive or negative) with an avid eating phenotype. The onset of negative affect during mealtime may be delayed when food is more rewarding (Gearhardt, 2018) and latency to onset positively associates with adiposity (Hendrikse et al., 2015). Alternatively, taking away food with high reward value elicits negative affect and resistance (Cramer & Antonides, 2011; Gearhardt, 2018; Gelman, Manczak, & Noles, 2012), which positively associates with intake (Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008) and adiposity (Hill, Saxton, Webber, Blundell, & Wardle, 2009; Temple et al., 2008). Indeed, in the single prior study examining negative affect in toddlers when food was taken away, a positive association with adiposity was detected (Asta et al., 2016). Finally we theorized that infants who actively resist relinquishing EAH foods when they are being removed at the end of the protocol may be exhibiting a greater "willingness to work" for food, and greater "willingness to work" for food positively associates with adiposity (Hill et al., 2009; Temple et al., 2008).

1.2 Correlates of and Risk Factors for Eating in the Absence of Hunger

Identifying EAH correlates and risk factors could also inform understanding of causal mechanism and therefore prevention strategies. However, literature on associations of EAH with sociodemographics, parent-reported eating behaviors, and dietary intake is remarkably sparse, with almost no studies examining correlates or predictors of EAH in infancy.

1.2.1 Sociodemographics

Though some studies have found more EAH in boys than girls in childhood (Savard 2022), most prior studies have found no association of child sex and EAH (Corsini et al., 2018; Savard et al., 2022; Schultink et al., 2021). The single prior study testing maternal age showed no association with EAH (Savard et al., 2022). Maternal education was associated with EAH in

one prior study of toddlers (Asta et al., 2016) but was not found to be associated in three studies with older children (Savard et al., 2022). The level of disorganization or environmental confusion in the home, deemed household chaos, is distributed across socioeconomic status and has been linked with adverse outcomes in children and families including greater adiposity in children (Marsh, Dobson, & Maddison, 2020). However, the two prior studies assessing the relationship of household chaos with EAH found no association (Asta et al., 2016; Savard et al., 2022).

1.2.2 Adiposity

Two studies have tested birthweight (Boone-Heinonen et al., 2019; Savard et al., 2022) as a predictor of EAH at preschool age, finding no association. In systematic reviews, most studies report a positive association between EAH and adiposity in children (Lansigan et al., 2015; Savard et al., 2022), though the null association in two studies with toddlers (Corsini et al., 2018; Schultink et al., 2021) raises the possibility that the association may only emerge at later ages. Three studies have tested maternal body mass index (BMI) as a predictor of EAH in toddlers, finding no association (Asta et al., 2016; Corsini et al., 2018; Schultink et al., 2021).

1.2.3 Eating Behaviors

Eating is driven by homeostatic need and reward (Carnell & Wardle, 2007; Gearhardt, 2018). Homeostatic-driven eating (i.e., satiety or satiation responsiveness) is a biological drive to maintain energy balance that is triggered by physiological signals, such as low energy stores (Camilleri, 2015), while reward-driven eating (i.e., enjoyment of food, food responsiveness) is motivated by pleasure. The contributions of homeostatic- and reward-driven eating to EAH in young children are not well-described. Homeostatic-driven eating can be challenging to measure by parent report, particularly in infancy (McCaffery et al., 2023). However, systematic reviews

including primarily preschool-aged children and older have reported generally null associations between parent-reported satiety responsiveness and EAH (Savard et al., 2022; Schultink et al., 2021; Tan et al., 2018). While associations of markers of reward-driven eating and EAH have been null among older children (Lansigan et al., 2015; Savard et al., 2022), positive associations have been reported in toddlers (Corsini et al., 2018; Schultink et al., 2021), suggesting the need for further study early in development.

Eating is also intertwined with emotion regulation processes (i.e., emotional overeating, food-related tantrums) (Russell & Russell, 2021). In systematic reviews, parent-reported child emotional overeating did not associate with EAH (Savard et al., 2022; Schultink et al., 2021). In contrast, food-related tantrums (Agras, Hammer, McNicholas, & Kraemer, 2004) and a temperament characterized by negative reactivity (Anzman-Frasca, Stifter, & Birch, 2012) have both been associated with greater adiposity. Nonetheless, the single other study testing the association of food-related tantrums with EAH intake showed no association (Leung et al., 2014).

1.2.4 Habitual Diet

Finally, habitual diet is of interest given its relevance as a potential target for prevention strategies, but has been the subject of surprisingly few studies. Systematic reviews among older children have reported positive associations of sugar-sweetened beverage intake and EAH among adolescents but inverse associations of obesogenic food availability in the household and EAH among school age children (Savard et al., 2022). Further, the two studies in toddlers have reported null associations between dietary intake of sweets and EAH (Asta et al., 2016; Corsini et al., 2018).

1.3 Objectives

Therefore, to better understand the origins and characteristics associated with EAH in infancy, this study had six objectives: (1) To examine how much 12-month-old infants eat in the absence of hunger when offered desserts after a typical meal; (2) To determine if microstructural features of eating behavior and affect observed during the EAH protocol correlate with one another and with intake to suggest an eating style high in food approach; and to determine if (3) sociodemographic characteristics, (4) maternal or infant adiposity, (5) parent-reported infant eating behaviors, or (6) infants' previous exposure to dietary sweets, are associated with EAH in infancy.

2 Methods

2.1 Participants and Recruitment

Infants were recruited from the community to participate in a longitudinal cohort study with data collection at up to six age-points across the first 12 months. The University of Michigan Institutional Review Board approved the study and mothers provided informed consent. Inclusion criteria were healthy, full-term infants in the physical and legal custody of the biological mother with birthweight appropriate for gestational age and without medical problems or food allergies. Mothers had to speak English, be older than 18 years, and be willing to offer a bottle-feeding by two months. Of the 284 infants enrolled, 120 participated in the EAH protocol at age 12 months (Figure 1). Specifically, of the 284 infants, 63 did not participate in any study activities at age 12 months. Of the 221 infants who participated in any study activities at age 12 months, 97 did not participate in the EAH protocol. Of those, 46 mothers learned about the details of the protocol from staff and declined to participate. Those 46 mother-infant dyads did not significantly differ from the 120 who participated on any tested characteristics, including infant sex (p=.86), maternal education (p=.72), maternal BMI (p=.61), CHAOS Total score

(*p*=.93), or infant's habitual dietary exposure to sweets (*p*=.40). The analytic (n=118) and excluded (n=166) samples did not differ on any tested characteristics except for greater maternal age and education in the analytic sample (Supplemental Table 1).

2.2 EAH Protocol

The entire protocol was conducted in the home. Mothers were asked to fast infants for at least one hour and to provide a typical meal in the usual seating arrangement, including a drink and a slightly greater amount than typical of at least two foods. Two infants were excluded because the meal provided was likely not adequate to ensure satiation. Detailed nutrition information was recorded (n=100) and double-entered into the Automated Self-Administered 24-Hour (ASA24®) Dietary Assessment Tool, from which nutritional composition variables were calculated. The reason for meal termination was recorded and meal duration calculated. Staff removed remaining food and drink and immediately presented a plate of cakes and donuts (hereafter, "desserts"). Staff told the infant, "Here are some special treats you can eat," ate one bite off the plate, and said "I'm going to have one, too. Mmm . . . this is really good. You can eat as much as you want." There was no further interaction from staff or mother. After seven minutes, staff declared, "All done!" and collected remaining desserts. The entire protocol was videotaped. Protocol characteristics are shown in Supplemental Table 2.

Desserts, shown in Table 1, were selected based on easy self-feeding and low choking and allergenicity risk. Only five infants had prior exposure to any of the desserts. Desserts were pre- and post-weighed in duplicate (H-9885; ULINE, precision ±0.01g). Because the supplier stopped producing one of the desserts after the first 56 participants, the last 60 participants received a replacement dessert that differed slightly from the original dessert.

Data collection was completed over 4.5 years by 10 staff with bachelor's degrees working full time on the overall longitudinal cohort study of infant eating behavior. Given evidence that familiarity with the food-eating model can influence eating behavior among young children (Harper & Sanders, 1975), we tested whether either the number or percentage of prior study home visits the research staff member had completed with the infant was associated with either of our two main study outcomes and found no significant associations.

2.3 Eating Avidity Index

Following prior methods for generating risk indices (Miller et al., 2018), we calculated an Eating Avidity Index (EAI) by assigning one point for each of twelve indicators of greater eating avidity. The twelve contributors were selected based on prior literature. The criterion used to result in a point being added to the EAI for each of the contributors is described below. The EAI had a potential range of 0 to 12, with a higher score indicating greater eating avidity.

2.3.1 Intake

Intake in kilocalories was calculated by subtracting post-weights from pre-weights and multiplying by the mean of the kilocalories per gram shown on the packaging label (Table 1) for the foods eaten. The potential range of total intake was 0 to 610 kilocalories. The criterion for a point being added to the EAI was total intake above the sample median (68.3 kcals).

2.3.2 Overall Approach to Behavioral Coding

We coded from videos behaviors observed during the EAH protocol. A detailed coding scheme was developed for this study. Definitions of behaviors were based on definitions in existing literature when available. Videos were coded using a detailed codebook in 10 second intervals. Coding began 10 seconds before the plate of desserts was presented to the infant and ended 30 seconds after the plate was removed. Two undergraduate student coders, a master's

student, and a full-time coding manager, who were separate from the data collection staff, were trained and supervised by the coding manager who was experienced in coding children's behavior from video. Coders were trained to inter-rater reliability (defined as Cohen's kappa (K)>0.70). Inter-rater reliability was confirmed periodically by having the coding team code approximately 10% of the corpus of videos to ensure that coders' reliability did not drift over time.

2.3.3 Definition of Eating

Although eating is often defined by number of bites, features of eating in this age range made it not possible to use this typical definition. We defined eating as food contacting any part of the mouth (Tan et al., 2018) during each 10-second interval (yes vs. no). This definition included licking but not ongoing chewing. We then summed the number of intervals in which eating occurred, resulting in a potential range of 0 to 42 intervals during which eating could have occurred. We henceforth refer to the count of intervals as "bites". Overall inter-rater reliability across all foods for number of bites was K=0.86.

2.3.3.1 Variety

We counted the number of desserts of which the infant took at least one bite (using the definition of bite given above, K ranged from 0.73 to 1.00 for the six foods) and included this as an ordinal variable, with a potential range of 0 to 5. The percent of participants who took at least one bite of each of the foods are shown in Table 1. Of the 114 infants, 32% took a bite of all five foods, 31% four foods, 16% three foods, 11% two foods, 5% one food and 5% no foods. The criterion for a point being added to the EAI was number of desserts tasted above the sample median (4 desserts).

2.3.3.2 Eating Duration

We defined eating duration as the number of intervals between the first interval during which a bite occurred and the last interval during which a bite occurred. For ease of interpretation, we converted this value to minutes by dividing by six (i.e., six 10 second intervals per minute), resulting in a potential range of 0 to 7. The criterion for a point being added to the EAI was eating duration above the sample median (6.17 min).

2.3.3.3 Eating Rate

We estimated eating rate as total intake (in kilocalories) divided by eating duration (i.e., the time in minutes between the first and last interval during which eating occurred, as defined above). If eating never occurred, eating rate was considered to be zero. The criterion for a point being added to the EAI was eating rate above the sample median (13.2 kcal/min).

2.3.3.4 Eating Latency

Eating latency was defined as the number of 10-second intervals between the interval when the plate of desserts was presented and the interval when eating (as defined above) first occurred (Fernandez et al., 2016). If the infant never took a bite, eating latency was considered to be the maximum number of intervals from plate presentation to plate removal (i.e., 42 intervals). For ease of interpretation, we converted intervals to minutes by dividing by six (i.e., six 10 second intervals per minute), resulting in a potential range of 0 to 7. The criterion for a point being added to the EAI was eating latency below the sample median (0.33 min).

2.3.3.5 Eating Engagement

We theorized that the more time that the infant spent eating the food while the food was present and available, the more of the infant's attention the food elicited. We therefore calculated eating engagement as a percentage defined as the number of eating intervals during which eating occurred divided by the eating duration (defined, as described above, as the number of intervals

between the first and last interval during which eating occurred), multiplied by 100 (Fogel et al., 2017; Klesges et al., 1983; Tan et al., 2018). The potential range was 0 to 100%. The criterion for a point being added to the EAI was eating engagement above the sample median (38.5%).

2.3.3.6 Bite Size

Bite size is commonly conceptualized as grams or kilocalories per bite (Fogel et al., 2017). Because, as described above, we are unable to count discrete bites in infants, we conceptualized bite size as intake (in kilocalories) divided by our proxy for bites (i.e., intervals during which eating occurred). Therefore, we calculated bite size as intake (in kilocalories) divided by the number of intervals during which eating was coded as occurring (converted to time in minutes). Importantly, this variable differs from eating rate in that the denominator for our eating rate variable is the entire duration of eating, whereas the denominator for bite size is the number of intervals during which eating occurred. Specifically, two infants could eat the same amount in the same eating duration (i.e., defined as interval from first to last bite), but bite size could differ substantially if one infant was eating during nearly every interval, while another infant was eating during very few intervals. The criterion for a point being added to the EAI was bite size above the sample median (25.8 kcal/min).

2.3.4 Positive Affect

We coded the highest observed intensity of positive affect during each interval as "none/neutral"=0, "mild/happy"=1 or "intense positive affect/exuberant/excited"=2 (K=0.74). Intense positive affect was very uncommon, occurring ever among only 51% of infants and overall in only 4% of intervals. Therefore, we collapsed positive affect as "any" vs. none" in each 10 second interval.

2.3.4.1 Positive Affect Before Tasting

An infant was categorized as showing positive affect before tasting the food if positive affect was coded as present during the one interval before the plate was placed on the tray, the interval during which the plate was placed on the tray, and/or the three intervals after the plate was placed on the tray or up until the first interval during which eating occurred (whichever occurred first), for a total of up to five intervals (50 seconds). The criterion for a point being added to the EAI was any positive affect occurring before tasting the food (as defined above), which occurred in 28% of the sample.

2.3.4.2 Positive Affect After Tasting

An infant was categorized as showing positive affect after tasting the food if positive affect was coded as present during any interval after eating first occurred. The criterion for a point being added to the EAI was any positive affect occurring after tasting the food (as defined above), which occurred in 73% of the sample.

2.3.5 Negative Affect

We coded the highest observed intensity of negative affect during each interval as "none/neutral"=0, "mild negative affect/distress/frustration"=1, or "moderate/intense negative affect/distress/frustration"=2 (K==0.86). Intense negative affect was very uncommon, occurring ever among only 25% of infants and overall in only 6% of intervals. Therefore, we collapsed negative affect as "any" vs. none" in each 10 second interval.

2.3.5.1 Latency to Negative Affect

We theorized that infants who showed negative affect sooner found food to be less rewarding—i.e., they became "bored" sooner because food did not have a high reinforcing value. We therefore calculated the number of intervals from plate presentation to the first interval in which negative affect was demonstrated prior to the interval just prior to plate removal. If

negative affect was never demonstrated prior to the interval just before plate removal, the infant was assigned a value equal to the total number of intervals between plate presentation and removal. For ease of interpretation, we converted this value to minutes by dividing by six (i.e., six 10 second intervals per minute), resulting in a potential range of 0 to 7. The criterion for a point being added to the EAI was latency to negative affect above the sample median (6.33 min).

2.3.5.2 Negative Affect in Response to Dessert Being Taken Away

We theorized that infants who demonstrated negative affect at plate removal found food rewarding and were distressed that the rewarding stimulus was being taken away. Negative affect in response to dessert being taken away was defined as negative affect coded in the single interval before plate removal and the interval during which plate removal occurred. The criterion for a point being added to the EAI was any negative affect occurring at plate removal (as defined above), which occurred in 11% of the sample.

2.3.6 Resistance to Relinquishment when Dessert was Taken Away

We captured resistance to relinquishment in several ways. Research staff recorded whether the child attempted to take food as the plate was being taken away (30% of infants), and coders coded in the 30 seconds after the plate was removed if the infant reached for the plate (12% of infants, K=1.00), “protested or was upset” (6% of infants, K=1.00), or refused to give the researcher the food in their hand or tried to eat it after the protocol had ended as the researcher tried to take it away (13% of infants, K=1.00). Infants were assigned one point for each of these 4 behaviors, such that the potential score for resistance was 0 to 4. Importantly, these behaviors do not necessarily need to occur with negative affect. The criterion for a point being added to the EAI was number of types of resistance above the sample median (0 types of attempts to resist).

2.4 Covariates

Mothers reported infant sex, birth date, race, ethnicity, gestational age, and birthweight; and their own birth date and education level; and completed questionnaires. The Confusion, Hubbub And Order Scale (CHAOS) consists of 15 true-false items about household organization that are summed (potential range 0 to 15), with higher scores reflecting greater chaos (Matheny Jr, Wachs, Ludwig, & Phillips, 1995). Mothers responded to the 29-item Children's Eating Behavior Questionnaire-Toddler (CEBQ-T) (Herle, Fildes, van Jaarsveld, Rijsdijk, & Llewellyn, 2016) on a scale of 1=never to 5=always and, after reverse scoring as appropriate, responses were averaged to generate subscale scores. We used subscales Satiety Responsiveness (internal reliability α=0.71) to reflect homeostatic-driven eating; Enjoyment of Food (α=0.85), Food Responsiveness (α=0.83), and Food Fussiness (α=0.84) to reflect reward-driven eating (Gearhardt, 2018); and Emotional Overeating (α=0.89) to reflect emotion-driven eating. Food-related tantrums were assessed as an indicator of emotion-driven eating with four questions asking how often in the last month the child asked for food, was denied, and tantrumed (Agras et al., 2004). Responses were categorized as 'asks for food at least once per day and tantrums when denied' versus not. Mothers reported sweet food (e.g., candy, cookies, cake) intake in the last week (Grummer-Strawn, Scanlon, & Fein, 2008; "Infant Feeding Practices II Study," 2013) and responses categorized as yes or no. Trained staff measured infant and maternal weight, infant length, and maternal height using standard protocols. Weight- and length-for-age and weight-for-length were calculated and World Health Organization z-scores generated. Maternal body mass index was calculated.

2.5 Statistical Analysis

Intake was not normally distributed and was square root transformed. After correcting for multiple comparisons, no tested protocol characteristics predicted either outcome (intake or EAI) and were therefore not considered further in analyses (Supplemental Table 2). Bivariate associations among contributors to the EAI were examined using Pearson, Spearman, or phi coefficient correlations. Unadjusted and adjusted regression analyses were used to evaluate associations with intake and EAI. Variables associated with outcomes in unadjusted analyses were included in adjusted models. Variables not associated with each outcome in these adjusted models were removed one-by-one starting with the variable with the highest p-value, resulting in the final model. Statistical significance was considered at $p<.05$.

3 Results

Table 2 shows cohort characteristics. The sample was 54% male and 68% non-Hispanic white. Mean infant birthweight was 3.4kg and mean infant weight-for-age z-score at 12 months was 0.1. Mean maternal age was 32.2yrs, 41% of mothers had more than a 4-year college degree, and mean maternal body mass index was 28.0. The infants' homes were relatively low in chaos, with a mean CHAOS Total score of 3.0. Mothers rated infants, on average, as exhibiting high enjoyment of food and low emotional overeating, and 23% of infants were reported to tantrum often for food when it was denied after they asked for it. Most (63%) of infants had been fed sweet food in the last 7 days.

Intake and behaviors exhibited during EAH are shown in Table 3. On average, infants first tasted a dessert M=0.63min after presentation and ate M=3.6 desserts totaling M=86.6kcals over M=5.55min at a rate of M=15.6kcal/min and a bite size of M=28.8kcal/min. On average, infants had food in their mouth M=38.3% of the time it was available to them. Positive affect was displayed by 28% of infants in anticipation of dessert before tasting it and 73% after tasting.

On average, infants first displayed negative affect after *M*=5.20min of the desserts being available. When the dessert was taken away, 13% showed negative affect and on average, there were *M*=0.5 attempts to resist relinquishment.

Table 3 shows bivariate associations among contributors to the EAI. Intake positively associated with variety, eating duration, rate, and engagement, and bite size. Variety positively associated with eating duration and engagement and negatively associated with eating latency. Eating rate positively associated with eating engagement and bite size. Eating duration positively associated with eating engagement and negatively associated with eating latency. Eating latency negatively associated with eating engagement. Positive affect before and after tasting were associated, as were latency to negative affect and negative affect when food was taken away, but there were no other associations with affect. On average, EAI was *M*=5.0 (*SD*=2.6, range 0-11), with an acceptable internal reliability (Cronbach's alpha= 0.61).

As shown in Table 4, sociodemographic (infant sex, maternal age and education, household chaos) and adiposity (infant birthweight and concurrent weight-for-age z-score and maternal body mass index) variables did not predict intake or EAI in either unadjusted or adjusted analyses. In final adjusted models, intake positively associated with enjoyment of food, food-related tantrums, and habitual intake of dietary sweets while EAI positively associated with enjoyment of food and habitual intake of dietary sweets.

4 Discussion

There were six main findings. First, 12-month-old infants showed substantial avidity for eating desserts after a typical meal. Second, many infants demonstrated multiple behaviors reflecting an eating style high in food approach, and many of these behaviors, with the notable exception of affect, correlated with intake with and one another. Third, sociodemographic factors

did not predict EAH. Fourth, neither maternal nor infant adiposity predicted EAH. Fifth, parent-reported eating behaviors reflective of reward- and emotion-driven eating, more so than those reflective of homeostatic-driven eating, predicted EAH. Sixth, exposure to sweets in the habitual diet predicted EAH in infancy.

4.1 Eating in the Absence of Hunger at Age 12 Months

Infants are robustly capable of self-regulating intake of a primarily milk- or formula-based diet in response to homeostatic need across the first year (Reynolds et al., 2023). The current study shows the power of sweet, palatable foods to overwhelm homeostatic-driven eating. After having just eaten a typical meal, 96% of 12-month-olds ate at least some dessert, even when the desserts were unfamiliar, and on average consumed a quantity of dessert in seven minutes equating to about 7-10% of their daily caloric needs. Most infants sampled multiple desserts and displayed positive affect.

4.2 Relationships Among Microstructural Features of Eating Behavior and Affect Observed During EAH with Intake

Infants displayed multiple behavioral indicators of avidity for eating dessert, and these behaviors correlated with intake and with one another, consistent with prior reports in preschoolers outside the EAH context (Fogel et al., 2017). Eating more dessert correlated with eating more variety, longer, faster, with more of the exposure time spent continuously bringing food to the mouth, and with larger bites. Starting to eat the desserts more quickly, though not associated with intake, associated with eating more variety, longer, and with more of the exposure time spent bringing food to the mouth. Future work should consider how the manner in which these behaviors correlate with one another may reflect eating styles with predictive value.

Displays of positive affect were common, occurring both before and even more commonly after tasting the food, but neither predicted intake. Displays of negative affect were less common, occurring in only 11% of infants, but also did not predict intake. Though different types of displays of positive and negative affect showed internal correlation, positive and negative affect did not correlate with each other. Our results align with reports of limited correlation of positive affective response with intake among school-age children (De Wijk et al., 2012; Zeinstra et al., 2009), but differ from findings in two prior studies with toddlers, in which negative affect in response to withholding (Miller et al., 2016) or taking away (Asta et al., 2016) dessert predicted greater adiposity. Further study of children's affective response to food is an important area for future research.

Overall, our findings suggest that a phenotype of "high food approach" might be detectable through measurement of intake as well as microstructural features of eating and affect during the eating in the absence of hunger protocol at age 12 months. The predictive value of these behaviors for eating behavior and adiposity later in childhood is unknown, though prior work demonstrating tracking from 18 to 24 months suggests this possibility (Schultink et al., 2021). Important potential next steps in this line of research are to determine if a vigorous sucking style in earlier infancy (Feldman et al., 2023) predicts a higher EAI at age 12 months, and whether a higher EAI at age 12 months predicts an eating style reflective of high food approach (Fisher et al., 2022; Mattsson et al., 2021; Pickard et al., 2023) at preschool or school age.

4.3 Associations of Sociodemographic Characteristics with EAH

Sociodemographic characteristics do not appear to be risk factors for EAH. Our null findings were consistent with multiple prior reports for infant sex (Corsini et al., 2018; Savard et

al., 2022; Schultink et al., 2021), with the single prior study testing maternal age (Savard et al., 2022), with three (Savard et al., 2022) of the four (Asta et al., 2016; Savard et al., 2022) studies testing maternal education, and with the two prior studies testing household chaos (Asta et al., 2016; Savard et al., 2022). These null findings suggest that ongoing investigation of biological etiologies, including genetics (Fisher et al., 2007; Wardle, Llewellyn, Sanderson, & Plomin, 2009; Yeum et al., 2024), will be important.

4.4 Associations of Maternal and Infant Adiposity with EAH

Neither intake nor eating avidity were predicted by birthweight, weight-for-age z-score, or maternal body mass index. Our null findings are consistent with the two prior studies examining birthweight (Boone-Heinonen et al., 2019; Savard et al., 2022) and the three prior studies in toddlers testing maternal body mass index (Asta et al., 2016; Corsini et al., 2018; Schultink et al., 2021). Our null finding for weight-for-age z-score was surprising, given that most studies in preschool and school-age children show a positive association with adiposity (Lansigan et al., 2015; Savard et al., 2022). However, our results were consistent with two (Corsini et al., 2018; Schultink et al., 2021) of the three (Asta et al., 2016; Corsini et al., 2018; Schultink et al., 2021) prior studies in toddlers. Further, our null results for eating avidity were surprising given prior reports of positive associations between a vigorous eating style, marked by faster eating rate and larger bites, and adiposity by preschool age (Fogel et al., 2017). Overall, results suggest that associations with adiposity may not emerge until children are older, perhaps because of cumulative effects over time.

4.5 Associations of Parent-Reported Infant Eating Behaviors with EAH

Intake and eating avidity were predicted by markers of reward- and emotion-driven eating. Enjoyment of food, a measure of response to environmental food cues and interest in

528 eating (Wardle, Guthrie, Sanderson, Birch, & Plomin, 2001) associated with both intake and the
529 eating avidity index, consistent with prior studies showing positive correlations with adiposity
530 (Carnell & Wardle, 2008). In addition, results were consistent with two (Corsini et al., 2018;
531 Schultink et al., 2021) of the three (Corsini et al., 2018; Schultink et al., 2021; Tan et al., 2018)
532 prior studies in toddlers showed a positive association of EAH intake with parent-reported
533 markers of reward-driven eating.
534 With regard to emotion-driven eating, parent-reported infant emotional overeating did not
535 associate with intake or eating avidity, consistent with prior reports of null associations with
536 intake (Savard et al., 2022; Schultink et al., 2021). In contrast, food-related tantrums associated
537 with intake. Though the single other study testing the association of food-related tantrums with
538 EAH intake showed no association (Leung et al., 2014), food-related tantrums (Agras et al.,
539 2004) and a temperament characterized by negative reactivity (Anzman-Frasca et al., 2012) have
540 both been associated with greater adiposity. The difference in findings for the two markers of
541 emotion-driven eating may be due to emotional overeating being defined by the child's distress
542 causing overeating—which parents uncommonly endorsed—whereas food-related tantrums are
543 defined by the child becoming distressed when they are not permitted to eat. This pattern of
544 distress resulting from denying the child food may be more reflective of reward-driven than
545 emotion-driven eating and deserves further study. Nonetheless, given prior work showing
546 positive associations of internalizing and externalizing behaviors with habitual dietary intake of
547 sweets in preschoolers (Vollrath, Stene-Larsen, Tonstad, Rothbart, & Hampson, 2012), negative
548 associations of capacity for recovery from distress in infancy and food reinforcement (Kong et
549 al., 2016), and positive associations of the use of food to soothe with risk of excessive weight
550 gain in very young children, particularly those with high temperamental negativity (Stifter,

Anzman-Frasca, Birch, & Voegtline, 2011), careful consideration should be given to how links between food reward and emotion-driven eating may develop very early in childhood, could be a risk factor for future weight gain, and may be reflected in behaviors exhibited during the EAH protocol in infancy.

Finally, the single measure purported to reflect homeostatic-driven eating, parent-reported satiety responsiveness—which asks if the child is satiated after eating or leaves food on their plate at the end of a meal—was not associated with intake or eating avidity, consistent with prior reports of null associations (Savard et al., 2022; Schultink et al., 2021; Tan et al., 2018). Although additional work is needed, overall, the pattern of results suggests a potentially stronger role for reward and emotion as compared to homeostasis in driving infants' behavioral response to and intake of dessert.

4.6 Associations of Habitual Dietary Intake of Sweets with EAH

Finally, intake and eating avidity were predicted by habitual dietary intake of sweets. This finding differs from prior work reporting null (Asta et al., 2016; Corsini et al., 2018) and inverse (Savard et al., 2022) associations of dietary intake of sweets with intake during EAH, and an inverse association with positive affect when dessert was presented in EAH (Asta et al., 2016). The reason for these discrepant findings is unclear. Nonetheless, given that diets high in added sugars established during complementary feeding track into childhood and contribute to obesity, diabetes, and hypertension risk (Gracner, Boone, & Gertler, 2024; Thompson, 2020), further consideration should be given to the potential role of early habitual dietary exposure to sweets in promoting the reward value of dessert and therefore increasing intake.

5. Limitations

The study had limitations. There was some missing data. The sample was of relatively high socioeconomic status and findings may not be generalizable to dissimilar groups. Only a subset of the full cohort participated. While cohort characteristics differed little by participation and mother-infant dyads who learned about the protocol and declined participation did not differ from those who participated on tested characteristics, including the infant's habitual dietary intake of sweets, mothers participating may have been more amenable to offering desserts.

Conducting the protocol at home may have introduced variability, but it provided ecological validity. Familiarity with the research staff member interacting with the infant could have influenced intake or EAI, though we found no association with either the number or percentage of prior study visits conducted by the research staff member with the infant. Further, the standardized enthusiastic invitation delivered by research staff to the infant to taste the desserts could have increased the likelihood that infants ate. Fasting time and mealtime varied, but neither associated with outcomes. Meal composition varied, but did not associate with outcomes and providing a typical, familiar meal increased likelihood of satiation. Assessment of infant satiation may have included error, but reason for terminating the meal did not associate with outcomes. One dessert was replaced mid-study due to shortages, but results did not differ by dessert. Meal nutritional composition estimates were imprecise, but did not associate with outcomes, consistent with prior literature (Corsini et al., 2018; Schultink et al., 2021). Results may have differed with salty snacks, but desserts were more ecologically valid after a meal and infants responded more to sweet than salty snacks in our prior work (Asta et al., 2016). Intake estimates included error due to inability to separately weigh desserts of differing energy density.

There are varied approaches to measuring EAH intake. Results did not differ when analyses were repeated using food weight or kcals per kilogram infant body weight. Videotaping

could have altered behavior. Alternative approaches to measuring eating behavior and coding affect (Zeinstra et al., 2009) may have greater sensitivity and should be a focus of future work. Weight-for-age is an indirect measure of adiposity. Results did not differ when analyses were repeated with weight-for-length.

6. Future Directions

There are several potential directions for future research. Our findings suggest that individual differences in eating avidity and food approach behaviors are detectable very early in the lifespan. Understanding the biological and environmental contributors occurring prenatally and in the first year after birth will be important to intervention and prevention efforts. Future work should also consider the predictive value of these observable behaviors in early infancy for lifespan trajectories of eating behavior and cardiometabolic health, as well as the modifiers of these trajectories. Finally, studies are needed that examine whether eating behavior phenotypes are present early in the lifespan, if those phenotypes are stable traits, and how eating behaviors correlate with one another and cluster. For example, it would be useful to understand how parent-reported infant eating behaviors relate to eating behaviors elicited through experimental manipulation. In addition, it would be useful to identify how eating behaviors elicited through experimental manipulation relate to one another. Specifically, determining how behaviors such as sucking vigor, eating in the absence of hunger, the ability to delay gratification, relative reinforcing value for food, and liking for sweet correlate with one another would help to inform conceptualization of eating behaviors and their development early in the lifespan.

7. Conclusions

Many infants as young as 12 months readily eat substantially beyond homeostatic need when offered desserts and some infants display behaviors during the EAH protocol that are

suggestive of the early origins of an avid eating or high food approach profile. Variety eaten, eating duration, rate, and continuous engagement, and bite size, predicted infants' dessert intake, suggesting that a vigorous eating style may confer risk for overeating and ultimately excess weight gain. Given that neither positive nor negative affective response to food while eating predicted intake, caregivers should use caution in making feeding decisions based on infant affective response during feeding. Given that parent-reported enjoyment of food, having food-related tantrums, and habitual dietary intake of sweets were the most robust predictors of infants' intake of and avidity for dessert, interventions focused on limiting exposure to foods with high reward value in early infancy may be effective in preventing excessive eating in the absence of hunger when children are offered sweet foods.

Acknowledgements

Conflict of Interest Disclosures: The authors have no financial relationships or conflicts of interest to disclose.

Funding/Support: This work was supported by the Eunice Kennedy Shriver National Institute of Child Health and Human Development R01HD084163

Role of Funder/Sponsor: The National Institute of Child Health and Human Development had no role in the design and conduct of the study.

Contributors' Statement

Dr. Katharine Asta made substantial contributions to the conception of the work and interpretation of data for the work, including contextualizing the work in prior literature, drafted portions of the work and reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Julie M. Sturza made substantial contributions to the conception of the work and interpretation of data for the work, including conducting the statistical analyses, drafted portions of the work and reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Dr. Niko Kaciroti made substantial contributions to the conception of the work and interpretation of data for the work, including directing the statistical analyses, reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Dr. Katherine L. Rosenblum made substantial contributions to the conception of the work and interpretation of data for the work, including contextualizing the work in prior literature, reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Dr. Ashley N. Gearhardt made substantial contributions to the conception of the work and interpretation of data for the work, including contextualizing the work in prior literature, reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Dr. Alison L. Miller made substantial contributions to the conception of the work and interpretation of data for the work, including directing the behavioral videocoding and contextualizing the work in prior literature, reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Hurley Riley made substantial contributions to the conception of the work and interpretation of data for the work, including directing the behavioral videocoding, reviewed the entire work for

important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

Dr. Julie C. Lumeng made substantial contributions to the conception and design of the work, the data acquisition, and interpretation of data for the work, drafted portions of the work, reviewed the entire work for important intellectual content, provided final approval of the version to be published, and agrees to be accountable for all aspects of the work.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

REFERENCES

Addessi, E., Galloway, A. T., Visalberghi, E., & Birch, L. L. (2005). Specific social influences on the acceptance of novel foods in 2–5-year-old children. *Appetite, 45*(3), 264-271.

Agras, W. S., Hammer, L. D., McNicholas, F., & Kraemer, H. C. (2004). Risk factors for childhood overweight: a prospective study from birth to 9.5 years. *The Journal of pediatrics, 145*(1), 20-25.

Agras, W. S., Hammer, L. D., McNicholas, F., & Kraemer, H. C. (2004). Risk factors for childhood overweight: a prospective study from birth to 9.5 years. *J Pediatr, 145*(1), 20-25. doi:10.1016/j.jpeds.2004.03.023

Anzman-Frasca, S., Stifter, C. A., & Birch, L. L. (2012). Temperament and childhood obesity risk: a review of the literature. *J Dev Behav Pediatr, 33*(9), 732-745. doi:10.1097/DBP.0b013e31826a119f

Asta, K., Miller, A. L., Retzloff, L., Rosenblum, K., Kaciroti, N. A., & Lumeng, J. C. (2016). Eating in the Absence of Hunger and Weight Gain in Low-income Toddlers. *Pediatrics, 137*(5). doi:10.1542/peds.2015-3786

Boone-Heinonen, J., Weeks, H. M., Sturza, J., Miller, A. L., Lumeng, J. C., & Bauer, K. W. (2019). Prenatal predictors of objectively measured appetite regulation in low-income toddlers and preschool-age children. *Pediatric obesity, 14*(11), e12554.

Camilleri, M. (2015). Peripheral Mechanisms in Appetite Regulation. *Gastroenterology, 148*(6), 1219-1233. doi:10.1053/j.gastro.2014.09.016

Carnell, S., & Wardle, J. (2007). Measuring behavioural susceptibility to obesity: Validation of the child eating behaviour questionnaire. *Appetite, 48*(1), 104-113. doi:https://doi.org/10.1016/j.appet.2006.07.075

Carnell, S., & Wardle, J. (2008). Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. *Am J Clin Nutr, 88*(1), 22-29. doi:10.1093/ajcn/88.1.22

Corsini, N., Kettler, L., Danthiir, V., & Wilson, C. (2018). Parental feeding practices to manage snack food intake: Associations with energy intake regulation in young children. *Appetite, 123*, 233-240. doi:10.1016/j.appet.2017.12.024

Cramer, L., & Antonides, G. (2011). Endowment effects for hedonic and utilitarian food products. *Food Quality and Preference, 22*(1), 3-10. doi:https://doi.org/10.1016/j.foodqual.2010.05.020

Davis, J. D. (1989). The microstructure of ingestive behavior.

De Wijk, R. A., Kooijman, V., Verhoeven, R. H., Holthuysen, N. T., & De Graaf, C. (2012). Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods. *Food Quality and Preference, 26*(2), 196-203.

Embling, R., Pink, A. E., Gatzemeier, J., Price, M., M, D. L., & Wilkinson, L. L. (2021). Effect of food variety on intake of a meal: a systematic review and meta-analysis. *Am J Clin Nutr, 113*(3), 716-741. doi:10.1093/ajcn/nqaa352

Feldman, K., Asta, K., Gearhardt, A. N., Sturza, J. M., Appugliese, D., Miller, A. L., . . . Lumeng, J. C. (2023). Characterization of a Vigorous sucking style in early infancy and its predictive value for weight gain and eating behaviors at 12 months. *Appetite, 185*, 106525.

Fernandez, C., Kasper, N. M., Miller, A. L., Lumeng, J. C., & Peterson, K. E. (2016). Association of Dietary Variety and Diversity With Body Mass Index in US Preschool Children. *Pediatrics, 137*(3), e20152307. doi:10.1542/peds.2015-2307

Field, M., & Cox, W. M. (2008). Attentional bias in addictive behaviors: A review of its development, causes, and consequences. *Drug and Alcohol Dependence, 97*(1), 1-20. doi:https://doi.org/10.1016/j.drugalcdep.2008.03.030

Fisher, J. O., & Birch, L. L. (1999). Restricting access to foods and children's eating. *Appetite, 32*(3), 405-419. doi:10.1006/appe.1999.0231

Fisher, J. O., Cai, G., Jaramillo, S. J., Cole, S. A., Comuzzie, A. G., & Butte, N. F. (2007). Heritability of hyperphagic eating behavior and appetite-related hormones among Hispanic children. *Obesity (Silver Spring), 15*(6), 1484-1495. doi:10.1038/oby.2007.177

Fisher, J. O., Hughes, S. O., Miller, A. L., Horodynski, M. A., Brophy-Herb, H. E., Contreras, D. A., . . . Appugliese, D. (2022). Characteristics of eating behavior profiles among preschoolers with low-income backgrounds: a person-centered analysis. *International Journal of Behavioral Nutrition and Physical Activity, 19*(1), 91.

Fogel, A., Goh, A. T., Fries, L. R., Sadananthan, S. A., Velan, S. S., Michael, N., . . . Toh, J. Y. (2017). A description of an 'obesogenic'eating style that promotes higher energy intake and is associated with greater adiposity in 4.5 year-old children: Results from the GUSTO cohort. *Physiology & behavior, 176*, 107-116.

Forestell, C. A., & Mennella, J. A. (2007). Early determinants of fruit and vegetable acceptance. *Pediatrics, 120*(6), 1247-1254.

Garcidueñas-Fimbres, T. E., Paz-Graniel, I., Nishi, S. K., Salas-Salvadó, J., & Babio, N. (2021). Eating Speed, Eating Frequency, and Their Relationships with Diet Quality, Adiposity, and Metabolic Syndrome, or Its Components. *Nutrients, 13*(5). doi:10.3390/nu13051687

Gearhardt, A. N. (2018). Role of reward pathways in appetitive drive and regulation *Pediatric food preferences and eating behaviors* (pp. 111-126): Elsevier.

Gelman, S. A., Manczak, E. M., & Noles, N. S. (2012). The nonobvious basis of ownership: Preschool children trace the history and value of owned objects. *Child Development, 83*(5), 1732-1747.

Gracner, T., Boone, C., & Gertler, P. J. (2024). Exposure to sugar rationing in the first 1000 days of life protected against chronic disease. *Science*, eadn5421. doi:10.1126/science.adn5421

Grummer-Strawn, L. M., Scanlon, K. S., & Fein, S. B. (2008). Infant Feeding and Feeding Transitions During the First Year of Life. *Pediatrics, 122*(Supplement 2), S36-S42. doi:10.1542/peds.2008-1315d

Guss, J., & Kissileff, H. (2000). Microstructural analyses of human ingestive patterns: from description to mechanistic hypotheses. *Neuroscience & Biobehavioral Reviews, 24*(2), 261-268.

Harper, L. V., & Sanders, K. M. (1975). The effect of adults' eating on young children's acceptance of unfamiliar foods. *Journal of experimental child psychology, 20*(2), 206-214.

Hendrikse, J. J., Cachia, R. L., Kothe, E. J., McPhie, S., Skouteris, H., & Hayden, M. J. (2015). Attentional biases for food cues in overweight and individuals with obesity: a systematic review of the literature. *Obes Rev, 16*(5), 424-432. doi:10.1111/obr.12265

Herle, M., Fildes, A., van Jaarsveld, C., Rijsdijk, F., & Llewellyn, C. H. (2016). Parental reports of infant and child eating behaviors are not affected by their beliefs about their twins' zygosity. *Behavior genetics, 46*, 763-771.

Hill, C., Saxton, J., Webber, L., Blundell, J., & Wardle, J. (2009). The relative reinforcing value of food predicts weight gain in a longitudinal study of 7--10-y-old children. *Am J Clin Nutr, 90*(2), 276-281. doi:10.3945/ajcn.2009.27479

Infant Feeding Practices II Study. (2013). Retrieved from http://www.cdc.gov/ifps/index.htm

Kininmonth, A., Smith, A., Carnell, S., Steinsbekk, S., Fildes, A., & Llewellyn, C. (2021). The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. *Obes Rev, 22*(5), e13169. doi:10.1111/obr.13169

Kininmonth, A., Smith, A., Carnell, S., Steinsbekk, S., Fildes, A., & Llewellyn, C. (2021). The association between childhood adiposity and appetite assessed using the Child Eating Behavior Questionnaire and Baby Eating Behavior Questionnaire: A systematic review and meta-analysis. *Obesity Reviews, 22*(5), e13169.

Klesges, R. C., Coates, T. J., Brown, G., Sturgeon-Tillisch, J., Moldenhauer-Klesges, L. M., Holzer, B., . . . Vollmer, J. (1983). Parental influences on children's eating behavior and relative weight. *Journal of applied behavior analysis, 16*(4), 371-378.

Kong, K. L., Anzman-Frasca, S., Feda, D. M., Eiden, R. D., Sharma, N. N., Stier, C. L., & Epstein, L. H. (2016). Infant temperament is associated with relative food reinforcement. *Childhood obesity, 12*(6), 411-417.

Lansigan, R. K., Emond, J. A., & Gilbert-Diamond, D. (2015). Understanding eating in the absence of hunger among young children: a systematic review of existing studies. *Appetite, 85*, 36-47. doi:10.1016/j.appet.2014.10.032

Laureati, M., Pagliarini, E., Toschi, T. G., & Monteleone, E. (2015). Research challenges and methods to study food preferences in school-aged children: A review of the last 15 years. *Food Quality and Preference, 46*, 92-102.

Leung, C. Y., Lumeng, J. C., Kaciroti, N. A., Chen, Y. P., Rosenblum, K., & Miller, A. L. (2014). Surgency and negative affectivity, but not effortful control, are uniquely associated with obesogenic eating behaviors among low-income preschoolers. *Appetite, 78*, 139-146. doi:10.1016/j.appet.2014.03.025

Llewellyn, C. H., van Jaarsveld, C. H., Boniface, D., Carnell, S., & Wardle, J. (2008). Eating rate is a heritable phenotype related to weight in children. *Am J Clin Nutr, 88*(6), 1560-1566. doi:10.3945/ajcn.2008.26175

Maneschy, I., Jimeno-Martínez, A., Miguel-Berges, M. L., Rupérez, A. I., Ortega-Ramiréz, A. D., Masip, G., & Moreno, L. A. (2024). Eating Behaviours and Dietary Intake in Children and Adolescents: A Systematic Review. *Curr Nutr Rep, 13*(3), 363-376. doi:10.1007/s13668-024-00544-w

Marsh, S., Dobson, R., & Maddison, R. (2020). The relationship between household chaos and child, parent, and family outcomes: A systematic scoping review. *BMC public health, 20*(1), 513.

Matheny Jr, A. P., Wachs, T. D., Ludwig, J. L., & Phillips, K. (1995). Bringing order out of chaos: Psychometric characteristics of the confusion, hubbub, and order scale. *Journal of applied developmental psychology, 16*(3), 429-444.

Mattsson, M., Murray, D. M., Kiely, M., McCarthy, F. P., McCarthy, E., Biesma, R., & Boland, F. (2021). Eating behaviour, physical activity, TV exposure and sleeping habits in five year olds: a latent class analysis. *BMC pediatrics, 21*(1), 180.

McCaffery, H., Zaituna, J., Busch, S., Kaciroti, N., Miller, A. L., Lumeng, J. C., . . . Pesch, M. H. (2023). Developmental trajectories of eating behaviors and cross-lagged associations with weight across infancy. *Appetite, 188*, 106978.

Miller, A. L., Gearhardt, A. N., Retzloff, L., Sturza, J., Kaciroti, N., & Lumeng, J. C. (2018). Early Childhood Stress and Child Age Predict Longitudinal Increases in Obesogenic Eating Among Low-Income Children. *Academic Pediatrics, 18*(6), 685-691. doi:https://doi.org/10.1016/j.acap.2018.01.007

Miller, A. L., Rosenblum, K. L., Retzloff, L. B., & Lumeng, J. C. (2016). Observed self-regulation is associated with weight in low-income toddlers. *Appetite, 105*, 705-712. doi:10.1016/j.appet.2016.07.007

Ohkuma, T., Hirakawa, Y., Nakamura, U., Kiyohara, Y., Kitazono, T., & Ninomiya, T. (2015). Association between eating rate and obesity: a systematic review and meta-analysis. *Int J Obes (Lond), 39*(11), 1589-1596. doi:10.1038/ijo.2015.96

Pearce, A. L., Cevallos, M. C., Romano, O., Daoud, E., & Keller, K. L. (2022). Child meal microstructure and eating behaviors: A systematic review. *Appetite, 168*, 105752.

Pickard, A., Croker, H., Edwards, K., Farrow, C., Haycraft, E., Herle, M., . . . Blissett, J. (2023). Identifying an avid eating profile in childhood: Associations with temperament, feeding practices and food insecurity. *Appetite, 191*, 107050. doi:https://doi.org/10.1016/j.appet.2023.107050

Remijn, L., da Costa, S., Bodde, C., Gerding, R., Weenen, H., Vereijken, C., & van der Schans, C. (2019). Hand motor skills affect the intake of finger foods in toddlers (12–18 months). *Food Quality and Preference, 74*, 142-146. doi:https://doi.org/10.1016/j.foodqual.2019.01.019

Reynolds, L. A., McCaffery, H., Appugliese, D., Kaciroti, N. A., Miller, A. L., Rosenblum, K. L., . . . Lumeng, J. C. (2023). Capacity for Regulation of Energy Intake in Infancy. *JAMA pediatrics, 177*(6), 590-598.

Russell, A., & Russell, C. G. (2021). Appetite self-regulation declines across childhood while general self-regulation improves: a narrative review of the origins and development of appetite self-regulation. *Appetite, 162*, 105178.

Savard, C., Bégin, S., & Gingras, V. (2022). Factors Associated with Eating in the Absence of Hunger among Children and Adolescents: A Systematic Review. *Nutrients, 14*(22). doi:10.3390/nu14224715

Schultink, J. M., de Vries, J. H. M., de Wild, V. W. T., van Vliet, M. S., van der Veek, S. M. C., Martens, V. E. G., . . . Jager, G. (2021). Eating in the absence of hunger in 18-month-old children in a home setting. *Pediatr Obes, 16*(11), e12800. doi:10.1111/ijpo.12800

Steiner, J. (1974). Discussion paper: innate, discriminative human facial expressions to taste and smell stimulation. *Annals of the New York Academy of Sciences*.

Steiner, J. E., Glaser, D., Hawilo, M. E., & Berridge, K. C. (2001). Comparative expression of hedonic impact: affective reactions to taste by human infants and other primates. *Neuroscience & Biobehavioral Reviews, 25*(1), 53-74.

Stifter, C. A., Anzman-Frasca, S., Birch, L. L., & Voegtline, K. (2011). Parent use of food to soothe infant/toddler distress and child weight status. An exploratory study. *Appetite, 57*(3), 693-699.

Stunkard, A., Berkowitz, R., Schoeller, D., Maislin, G., & Stallings, V. (2004). Predictors of body size in the first 2 y of life: a high-risk study of human obesity. *International journal of obesity, 28*(4), 503-513.

Tan, C. C., Walczak, M., Roach, E., Lumeng, J. C., & Miller, A. L. (2018). Longitudinal associations between eating and drinking engagement during mealtime and eating in the absence of hunger in low income toddlers. *Appetite, 130*, 29-34. doi:https://doi.org/10.1016/j.appet.2018.07.029

Temple, J. L., Legierski, C. M., Giacomelli, A. M., Salvy, S. J., & Epstein, L. H. (2008). Overweight children find food more reinforcing and consume more energy than do nonoverweight children. *Am J Clin Nutr, 87*(5), 1121-1127. doi:10.1093/ajcn/87.5.1121

Thompson, A. L. (2020). Evaluating the pathways linking complementary feeding practices to obesity in early life. *Nutr Rev, 78*(Suppl 2), 13-24. doi:10.1093/nutrit/nuz057

van den Akker, K., Bongers, P., Hanssen, I., & Jansen, A. (2017). Validation of prospective portion size and latency to eat as measures of reactivity to snack foods. *Appetite, 116*, 480-486. doi:10.1016/j.appet.2017.05.049

Vilela, S., Hetherington, M. M., Oliveira, A., & Lopes, C. (2018). Tracking diet variety in childhood and its association with eating behaviours related to appetite: The generation XXI birth cohort. *Appetite, 123*, 241-248. doi:10.1016/j.appet.2017.12.030

Vollrath, M. E., Stene-Larsen, K., Tonstad, S., Rothbart, M. K., & Hampson, S. E. (2012). Associations between temperament at age 1.5 years and obesogenic diet at ages 3 and 7 years. *Journal of Developmental & Behavioral Pediatrics, 33*(9), 721-727.

Wardle, J., Guthrie, C., Sanderson, S., Birch, L., & Plomin, R. (2001). Food and activity preferences in children of lean and obese parents. *Int J Obes Relat Metab Disord, 25*(7), 971-977. doi:10.1038/sj.ijo.0801661

Wardle, J., Llewellyn, C., Sanderson, S., & Plomin, R. (2009). The FTO gene and measured food intake in children. *Int J Obes (Lond), 33*(1), 42-45. doi:10.1038/ijo.2008.174

Yeum, D., Renier, T. J., Masterson, T. D., Carlson, D. D., Ballarino, G. A., Lansigan, R. K., . . . Gilbert-Diamond, D. (2024). Genetic associations with consumption of palatable foods in the absence of hunger in response to food cues in children. *Pediatr Obes*, e13168. doi:10.1111/ijpo.13168

Zeinstra, G. G., Koelen, M., Colindres, D., Kok, F., & De Graaf, C. (2009). Facial expressions in school-aged children are a good indicator of 'dislikes', but not of 'likes'. *Food Quality and Preference, 20*(8), 620-624.