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Ecological momentary assessment of eating and dietary intake behaviors in children and adolescents: A systematic review of the literature

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Abstract

The objective of this review was to summarize associations between ecological momentary assessment (EMA)-measured contextual factors and eating and dietary intake behaviors in children and adolescents. The inclusion criteria were availability of the study in English and use of EMA to study eating and dietary intake behaviors among children and/or adolescents (ages < 18).

Literature searches were conducted in PsycInfo and PubMed databases across all dates until December 2018. A modified Checklist for Reporting EMA Studies was used to assess quality of studies. Eighteen articles from 15 independent studies were included in the systematic review.

Contextual factors examined in relation to children's eating in studies included affect and stress; cognitive factors; social and environment factors; behavioral factors; and caregiver-related factors. Studies suggested there is strong evidence that cognitive and social factors have an effect on eating and dietary intake behaviors while the association between affect and eating and dietary intake behaviors remains mixed. Future studies should consider timing of effects, measure choice, individual difference and contextual factors, and developmental context.

Keywords

Diet; Eating; Ecological momentary assessment; Children; Adolescents

Eating is a complex behavior that can involve regular dietary intake and dysregulated intake patterns. Measures of dietary intake typically involve overall caloric intake, consumption of macronutrients (i.e., carbohydrates, fats, and proteins) and micronutrients (e.g., vitamins and minerals), and various food types (e.g., high sugar foods, fruit/vegetables, foods high in saturated fats). Dysregulated eating comprises a variety of eating patterns that often occur in response to environmental and internal cues unrelated to hunger (e.g., affect, sight or smell of food). Two commonly studied forms of dysregulated eating include emotional eating (i.e., eating in response to mood) and binge eating (i.e., eating an objectively large amount of food with a subjective sense of loss of control over eating).

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Conflicts of interest

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Individuals with poorer diet quality (i.e., diets high in sugar and saturated fat and low in fruit/vegetables) and/or who engage in dysregulated eating behaviors (e.g., binge eating, emotional eating) are more likely to develop an array of mental and physical health problems (Dauchet, Amouyel, Hercberg, & Dallongeville, 2016; Ford & Mokdad, 2001; Jacka, Rothon, Taylor, Berk, & Stansfeld, 2013; Neumark-Sztainer, Wall, Guo, Story, Haines, & Eisenberg, 2016; O'neil et al., 2014). In particular, poor eating and dietary intake behaviors are related to increased body weight (Morgan et al., 2002; Te Morenga, Mallard, & Mann, 2013), which may mediate associations among eating and dietary intake behaviors and numerous health conditions such as cardiovascular disease, diabetes, and cancer (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011).

Childhood and adolescence are important developmental periods for early prevention and intervention of eating and dietary intake behaviors as these periods are critical times for the development of obesity and eating behaviors (Alberga, Sigal, Goldfield, Prud'Homme, & Kenny, 2012; Fergus & Zimmerman, 2005). Further, higher body weight in adolescence is predictive of weight trajectory in adulthood (Reilly & Kelly, 2011; Wang, Chyen, Lee, & Lowry, 2008). Modification of various types of eating and dietary intake behaviors during the earlier years are important to increase positive health outcomes.

Theoretical models of eating and dietary intake behaviors among children and adolescents focus on an array of factors that cross multiple levels including individual, family, school, community, and society (Davison & Birch, 2001). These factors each play an important individual and interactive role in children and adolescents' dietary intake, eating-related decisions, and home food environment (Rosenkranz & Dziewaltowski, 2008). However, models typically focus on how such cross-cutting factors vary between (e.g., trait depression, neighborhood environments, usual levels of parental support) rather than within (e.g., state negative affect, personal environmental exposures, momentary levels of parental support) children and adolescents.

Concordantly, assessments of constructs of interest typically involve singular completion of measures cross-sectionally or longitudinally across extended periods of time, and responses are then used to represent individuals' usual level of that construct. For example, a cross-sectional questionnaire may be given to assess coping strategies, and the score on the measure will represent each participant's level of various coping strategies. However, research shows that coping strategy use varies across a day and over a week, and reports of coping assessed in daily life show poor correspondence with cross-sectional questionnaire measures (Stone et al., 1998). Consequently, more research is needed that considers how factors vary within children and adolescents to inform and refine current theoretical models (e.g., how do children's own fluctuations in mood, environment, and social experiences relate to their own fluctuations in eating?). Specifically, this may have important implications for developing models of micro-temporal processes (i.e., processes that unfold over a short period of time such as minutes or hours) that predict the occurrence of eating and dietary intake behaviors (Dunton, 2018). An example of a micro-temporal process in the eating literature is the affect regulation model of binge eating which suggests that momentary states of negative mood precipitate binge eating over the next few hours (Haedt-Matt & Keel, 2011).

Literature suggests that temporal and situational cues are salient drivers of eating and dietary intake behaviors in the moment (Dunton, 2018). For example, an individual's physical and social environment as well as internal states (e.g., affect or stress level) may be key determinants of their eating-related decisions on a moment-to-moment basis. Historically, laboratory paradigms have been utilized to understand momentary determinants of eating and dietary intake behaviors (Tanofsky-Kraff, Haynos, Kotler, Yanovski, & Yanovski, 2007). Commonly, laboratory paradigms experimentally invoke state factors of interest (e.g., affective or stressful state) in a carefully controlled environment and subsequently put participants in an eating-related situation (e.g., sham taste test, buffet meal; Tanofsky-Kraff et al., 2007). While laboratory paradigms allow for causal conclusions, they lack ecological validity—or generalizability to people's everyday lives and natural environment.

Ecological momentary assessment (EMA) is a real-time, naturalistic assessment methodology that involves individuals completing one or more daily reports of their experiences over the course of a short period of time (e.g., a week) and overcomes some of the disadvantages of laboratory paradigms. Advantages of EMA are that assessments occur in people's natural environments (real-world) and temporally close to actual experiences (real-time), thus limiting retrospective recall biases and maximizing ecological validity (Shiffman, Stone, & Hufford, 2008). There are a number of cognitive recall biases that are inherent in typical self-report measures that can be reduced by EMA. These include recency bias (i.e., recent events are more easily remembered), saliency (i.e., salient events are more easily recalled), effort after meaning (i.e., tendency to reconstruct events so that they are consistent with subsequent events), and aggregation of events (Yoshiuchi, Yamamoto, & Akabayashi, 2008). EMA data can be disaggregated into between-subjects (trait) and within-subjects (state) components to allow for examination of state-trait effects on outcomes. Further, EMA allows researchers to assess temporality of variables such as assessment of time-related antecedents and consequences of behaviors, states, and contexts.

Consistent with broad theoretical models of obesity (Davison & Birch, 2001; Rosenkranz & Dzewaltowski, 2008), EMA and related work has elucidated a number of factors across various levels (e.g., individual, family, social, and environmental) that are associated with eating and dietary intake behaviors. Individual factors such as one's momentary emotional state and stress level have been shown to be related to eating (Engel et al., 2016). Interpersonal factors, including who one is with, and interpersonal stressors can facilitate food intake (de Castro, 1994; De Castro & Brewer, 1992; Mason, Heron, Braitman, & Lewis, 2016). Further, environmental factors including the presence of palatable food and the time of day can impact food intake. For example, increased presence of palatable foods is associated with unhealthy eating, and unhealthy eating is more common at night (de Castro, 2004; Goldschmidt et al., 2017).

A recent review reported that EMA is feasible to use with children and adolescents, although, compliance—which refers to the proportion of daily EMA surveys that participants complete—is not always optimal (Wen, Schneider, Stone, & Spruijt-Metz, 2017). Researchers have begun to use EMA to study eating and dietary intake behaviors including the micro-temporal processes underlying these behaviors, but primarily in adults. Although there is a burgeoning area of research studying eating and dietary intake behaviors,

this research area is still emerging and is heterogeneous with regard to study goals. The purpose of the current paper was to systematically review the literature using EMA to assess eating and dietary intake behaviors among children and adolescents in order to advance this field of research. To this end, the objectives of this review were to describe the methods used and results of EMA studies on the associations between contextual factors and eating and dietary intake behaviors in children and adolescents.

1. Method

The protocol was pre-registered online in PROSPERO (#CRD42019116551). Literature searches in PsycInfo and PubMed databases were conducted across all dates (up to December 2018) using the following terms: “eating” and “diet” paired with “ecological momentary assessment” and “EMA” and “children”, “adolescents”, “teens”, and “youth.” The inclusion criteria were availability of the study in English and use of EMA to study associations between contextual factors and eating and dietary intake behaviors among children and/or adolescents (all ages < 18). Studies were excluded that used EMA but aggregated findings to the between-person level. Reference sections of identified articles were searched for possible additional studies. Articles were screened by two authors (BD and SW) to avoid errors. The abstracts were first screened for inclusion. Studies that appeared to meet inclusion were further screened for possible inclusion. See Fig. 1 for the flow diagram of article selection using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We identified 18 articles from 15 independent studies for inclusion in the review. Data were extracted from the studies and are summarized in Table 1. Three authors (TM, BD, and SW) extracted data; each study had data extracted by at least two authors.

In Table 1, the sample, EMA protocol, and measures were described. Then, all associations between contextual factors and eating and dietary intake behaviors were reported. Frequencies and percentages are calculated out of the 15 independent studies; reports of the same data are grouped together. After the review of the literature, associations between each type of contextual factor and eating were summarized into several broad content categories for ease of presentation. Categories included affect and stress; cognitive factors; social and environmental factors; behavioral factors; and caregiver-related factors. Results focus on within-person associations. Table 2 synthesizes the data extracted from the studies.

Two authors created a quality score for each study using a modified version of the Checklist for Reporting of EMA Studies (CREMAS; Liao, Skelton, Dunton, & Bruening, 2016). The scale was used to assess training participants received on the EMA protocol, technology used for EMA surveys (i.e., operating system, device type, and/or phone model), wave duration (i.e., number of separate bursts of EMA), monitoring period (i.e., number of days an EMA wave lasted), prompting schedule, prompt frequency, attrition, latency (i.e., time to completion of surveys), compliance rate, missing data, and limitations. The lowest possible quality score was zero, and the highest quality score possible was eleven. Appropriate reliability was confirmed ($\kappa = .71$) and score disagreements were resolved by consensus, and a final rating was provided for each study.

2. Results

2.1. Quality coding and sample, methods, and measurement of eating and dietary intake variables

The mean quality score of studies was 7.52 ($SD = 1.54$; Range: 4–10). The mean sample size of studies was 229.27 participants ($SD = 297.81$; Median = 100; Range = 17–884). The mean age of children across studies was 12.11 ($SD = 4.42$; Range = 1.67–17.00). Almost half (46%) of studies included adolescents only (age = 13–18), 27% of studies included children only (age < 13), and 27% of studies included both children and adolescents. The lowest age children included in studies was 1.5 years old, which involved parental completion of surveys; eight years old was the youngest when the child completed EMA surveys themselves.

All studies were observational, with one study also using EMA in the context of a healthy eating intervention (i.e., Marx, 2017), 65% of studies had one wave and 35% had multiple waves. For completion of EMA protocols, 47% of studies used smartphones, 33% used personal digital assistants, and 20% used paper diaries. Most studies only used self-report EMA (53%) with 29% of studies also using accelerometers, 7% ($n = 1$) using global positioning systems (GPS), and 7% ($n = 1$) using Holter monitors (i.e., ambulatory devices measuring heart activity). With regard to EMA signal schedules, the majority of studies (47%) used a combination of signal-contingent (i.e., surveys automatically administered to participants on a semi-random basis throughout the day), event-contingent (i.e., surveys initiated by participants directly before or following eating), and interval-contingent recordings (i.e., surveys administered at the same time each day); the rest used only one type of signal schedule: interval-contingent recordings only (33%) or signal-contingent recordings only (20%). Most studies (80%) had children complete EMA reports of their own eating and contextual factors; three studies (20%) had parents complete reports for their child (Campbell et al., 2018; Mak et al., 2012; Marx, 2017). EMA recordings typically did not occur during school-time.

Eating and dietary intake behaviors investigated within studies included normative dietary intake alone (60%), disordered eating alone (26%), both normative and disordered eating (7%), and one examined eating versus not eating (7%). Some studies examined specific foods/ food groups (e.g., fruit/vegetables, pastries/sweets), while other studies used categories such as unhealthy foods or healthy foods. Studies that examined disordered eating typically focused on loss of control eating (i.e., feelings of a subjective sense of loss of control over eating) and used a dichotomous or Likert-type rating scale.

2.2. Associations of affect and stress with eating and dietary intake

Affect and stress were examined in 60% of studies; although, specific constructs varied widely. Nine studies examined negative affect in relation to eating. In a sample of adolescents, Grenard et al. (2013) found that loneliness was related to increased sweet drink consumption, and boredom was related to increased sweet food consumption. In addition, higher subject-level variability of negative affect assessed via EMA (i.e., more fluctuations in negative affect across the EMA period) was associated with less healthy and more

unhealthy dietary intake in 8–13-year-old children (O'Reilly et al., 2016). Further, Ranzenhofer et al. (2016) found that higher momentary heart rate variability (i.e., fluctuations in heart rate in the 30-min prior to eating)—conceptualized as a psychophysiological indicator of negative affect—predicted more loss of control eating in adolescent girls. Kolar, Hammerle, Jenetzky, Huss, and Bürger (2016) also found that eating was positively associated with aversive tension (i.e., emotional state of intense arousal and negative valence) in adolescent girls with anorexia nervosa but not healthy controls. Finally, worry was related to increased thoughts of binge eating in a sample of adolescents with non-suicidal self-injury (Shingleton et al., 2013). However, several studies of children and adolescents spanning ages of 8–17 have reported that momentary negative affect did not precipitate loss of control eating (Goldschmidt et al., 2018; Hilbert, Rief, Tuschen-Caffier, de Zwaan, & Czaja, 2009; Ranzenhofer et al., 2014) nor unhealthy food intake (Grenard et al., 2013; Mason et al., 2019).

Three studies examined stress in relation to eating. In a study of 8–12-year old children, lower momentary ability to cope with stress prospectively predicted greater subsequent intake of sugary foods (Mason et al., 2019). Although, other studies of children and adolescents found no relations between momentary stress and loss of control eating (Goldschmidt et al., 2018) nor food and drink intake (Dunton et al., 2017; Grenard et al., 2013).

Four studies investigated associations between positive affect and eating. In 8–14-year-old children with loss of control eating, less happiness preceded both regular and loss of control eating episodes (Hilbert et al., 2009). In addition, Grenard et al. (2013) found that feeling more energetic was positively associated with sugary drink consumption in adolescents. Other studies of children and adolescents have reported null findings between momentary positive affect and eating and dietary intake behaviors as well (Grenard et al., 2013; Mason et al., 2019) and positive affect variability and diet (O'Reilly et al., 2015).

2.3. Associations of cognitive factors with eating and dietary intake

Cognitive factors were examined in 33% of studies, and many studies focused on food-related cognitive factors such as cravings and perceived palatability. Cravings for food and drink and being exposed to food cues were related to unhealthy food and drink consumption in adolescents (Grenard et al., 2013). Further, greater than usual perceived palatability of food being consumed (i.e., momentary food hedonics) was associated with greater loss of control severity in 8–14-year-old youth (Goldschmidt et al., 2018). Similarly, Hilbert et al. (2009) reported that loss of control eating episodes were preceded and followed by cognitions about food/eating and body image in 8–13-year-old youth. In a study of adolescents, Bejarano and Cushing (2018) found that daily hedonic hunger (i.e., extreme drive to consume food) was only related to starchy food consumption and not sweet or fatty food consumption or fast food intake. In addition, increased daily hedonic hunger was positively related to starchy food consumption in adolescents with higher trait-level controlled motivation (i.e., motivation to eat healthy for external reasons), and increased daily hedonic hunger was negatively related to fast food intake in adolescents with higher

trait-level autonomous motivation (i.e., motivation to eat healthy for intrinsic reasons; Bejarano & Cushing, 2018).

One study focused on non-food specific cognitions and thoughts of binge eating in adolescents with non-suicidal self-injury (Shingleton et al., 2013). The majority of binge eating thoughts co-occurred with other self-destructive thoughts, and feeling pressure, perceived criticism, and rejection/hurt commonly occurred along with binge eating and/or purging thoughts (Shingleton et al., 2013).

2.4. Associations of social and environment factors with eating and dietary intake

Social and environment factors were examined in 47% of studies. Environmental factors were examined in four studies. In a large sample of children between the ages of 1.5 and 10 years, Mak et al. (2012) reported the majority of eating episodes occurred at home, and a third of eating episodes occurred with parents. Children aged 1.5–3 years old were more likely to consume fruit at care outside their home compared to at home and fruit and vegetables with a caregiver and other children/others compared to with parents (Mak et al., 2012). Children of all ages were more likely to eat vegetables at a table than not at a table (Mak et al., 2012), and toddlers were more likely to eat fruits or vegetables at a table or high chair (Campbell et al., 2018). Further, there were associations between not being in a high chair, moving around, and eating alone and snack consumption among toddlers (Campbell et al., 2018). In studies of adolescents, sweet and salty snack consumption was related to being at school (Grenard et al., 2013), and adolescents consumed the largest non-core energy intake at “eateries” (Toumpakari, Tilling, Haase, & Johnson, 2019).

Six studies (40%) examined social factors. Being with others, such as friends, family, and co-workers, was associated with unhealthy dietary intake among urban adolescents (Grenard et al., 2013; Toumpakari et al., 2019). Oppositely, children aged 4–6 years old were more likely to consume fruit and vegetables with friends compared to at home (Mak et al., 2012). In a large sample of children between the ages of 1.5 and 10 years, both the frequency of eating alone and with friends increased with age (Mak et al., 2012). Further, among adolescents, momentary interpersonal problems (Ranzenhofer et al., 2014) and rejection (Shingleton et al., 2013) were associated with loss of control eating and thoughts of binge eating, respectively.

2.5. Associations of other health behaviors with eating and dietary intake

Associations with other health behaviors were examined in seven studies (41%). Six of these studies looked at relations between sedentary behaviors (including electronic and television use) and eating, and three studies examined associations between physical activity and eating. Sweet drink consumption was related to increased physical activity in adolescents, but physical activity was unrelated to food consumption (Grenard et al., 2013). Among 8–14-year-old youth travel soccer players, sports games days were associated with fast food consumption compared to practice and non-sports days but not individual food and drink intake (Marx, 2017). In a separate study, 8–12-year-old children were more likely than their mothers to consume unhealthy foods during 2-h EMA windows that included physical activity; there were no differences between children and mothers in 2-h EMA windows for

sedentary behavior (O'Connor et al., 2017). Also, sweet snacks were associated with watching television and using electronic media in adolescents (Grenard et al., 2013), and consumption of vegetables was higher when the TV was off than on in children from 1.5 years to 10 years old (Mak et al., 2012).

One study also reported demographic differences in the relationship between sedentary activities and cravings for unhealthy food and drinks in adolescents (Borgogna et al., 2015). Non-Hispanic adolescents showed stronger associations between television exposure and cravings for sweet snacks, salty snacks, and sweetened drinks compared to Hispanic adolescents, and Hispanic adolescents showed stronger associations between phone messaging and cravings for sweet snacks, salty snacks, and sweetened drinks compared to non-Hispanic adolescents. Further, males showed stronger associations between video game use and salty snack cravings compared to females.

2.6. Association of caregiver-related factors with eating and dietary intake

One study (7%) examined caregiver-related factors. Children engaged in more healthy and unhealthy eating on days when their mothers also engaged in more healthy and unhealthy eating, respectively (Dunton et al., 2017). In addition, lower momentary ability to cope with stress among mothers prospectively predicted greater subsequent intake of sugary foods in their child (Mason et al., 2019). Although, mothers' momentary negative and positive affect had no effect on their child's food intake (Mason et al., 2019).

3. Discussion

This systematic review highlighted the extant EMA associative research on eating and dietary intake behaviors among children and adolescents. Below, we discuss EMA methodology used in studies, findings of EMA studies on contextual factors and eating, and recommendations for future research.

3.1. EMA methods and assessment of eating and dietary intake behaviors

EMA methods and assessment used in studies varied in signaling strategies used, subject population, and location/timing of prompts. Methodology for assessing eating and dietary intake behaviors in EMA has utilized signal-, event-, and fixed-interval approaches. The majority of studies employed multiple signaling strategies, which is advantageous as it allows for examination of event antecedents and consequences, comparison of events versus non-events, and provides more data across the day (Shiffman, 2007).

A previous review of children's compliance to EMA has shown that compliance (i.e., proportion of prompts that participants complete) in EMA research is reasonable among children and adolescents, but often does not reach 80% compliance, which has been offered by other researchers as a minimum criterion for compliance (e.g., Stone & Shiffman, 2002; Wen et al., 2017). Thus, there may be concerns with using event-contingent recordings for eating and dietary intake behaviors with children and adolescents as we cannot be sure how many eating episodes were missed. Some researchers allow individuals to input missing eating episodes during signal-contingent recordings (Goldschmidt et al., 2018); this may reduce missing eating events but would be subject to some retrospective recall bias and

uncertainty of event timing. Further, this strategy may complicate the EMA protocol and may be difficult for children to understand. A summary approach within signal-contingent recordings, where children report on their eating and dietary intake behavior over the past several hours, has also been used (Mason et al., 2019), but exact timing of eating would be unknown.

The majority of studies included in this review examined eating and dietary intake behaviors among adolescents, particularly studies of disordered eating (which often begins to develop in adolescence; Slane, Klump, McGue, & Iacono, 2014). In addition, adolescence is associated with increased autonomy in decisions, and this includes more individual choice for eating and dietary intake behaviors, particularly in late adolescence (Spear & Kulbok, 2004). In our review, children as young as eight completed EMA surveys with appropriate compliance and understanding of the protocol. However, similar to traditional survey design principles in children (de Leeuw, 2011), careful attention should be given to items used in EMA surveys. For example, a validation study of the Self-Administered 24-Hour Dietary Recall for children found low concordance between 9 and 11-year old children's recall estimates and objective consumption estimates (Diep et al., 2015); therefore, it is possible that younger children have reduced ability to distinguish between various food types as well as portion size.

EMA studies typically assessed any eating that occurred outside of school hours, which could include food consumed in and out of the child's home. Although, some studies examined the locations where various eating and dietary intake behaviors occurred; none investigated contextual factors associated with eating and dietary intake behaviors at different locations (e.g., the home versus outside the home). Omission of eating and dietary intake behaviors that occur at school is often due to practical and ethical reasons. Although, research suggests that the majority of children's eating occurs at home, particularly in younger children, (Mak et al., 2012), school-time eating still represents a portion of children's overall eating and may include consumption of unhealthy foods (Grenard et al., 2013). Parents and schools may not allow their child to participate in an EMA study if it will disrupt his or her learning. Additionally, from an ethical standpoint, it may not be ethical to disrupt children's learning for research purposes. Further, eating and dietary intake behaviors at school may be quite complex. On one hand, food intake at school is subject to caregiver choice (packed lunches) or school availability. Previous research suggests that packed lunches are typically healthier than school lunches (Rees, Richards, & Gregory, 2008); thus, predictors of food consumed at school may explained in part by parental factors. On the other hand, children and adolescents often have choice as to what they order at school and/or actually consume. Also, they may trade food with other children or purchase additional snacks/beverages at lunch or in vending machines, which is important to capture (Baxter, Thompson, & Davis, 2001; Neumark-Sztainer, French, Hannan, Story, & Fulkerson, 2005; Rovner, Nansel, Wang, & Iannotti, 2011). Some schools have open lunch policies (e.g., can get food off-campus), which increases the probability of consumption of fast food for lunch (Neumark-Sztainer et al., 2005). There may be important momentary factors that determine children's food choices in the school environment such as stress and peer relations that should be investigated. Increasing the use of EMA to study school-time eating

could potentially inform future policy recommendations—such as lunch offerings and limiting access to unhealthy foods or fast food.

3.2. Associations between EMA contextual factors and eating and dietary intake behaviors

In general, the current findings on correlates of EMA eating and dietary intake behaviors among children and adolescents is largely mixed. Affect and stress were the most commonly examined contextual factors, and findings on the association between affect and stress and eating and dietary intake behaviors among children and adolescents have been mixed. Cognitive and social factors have largely been found to be related to eating and dietary intake behaviors in children and adolescents. Increased momentary or daily cravings, food cues, and food hedonics were associated with unhealthy eating and dietary intake behaviors (Bejarano & Cushing, 2018; Goldschmidt et al., 2018; Grenard et al., 2013; Hilbert et al., 2009). Also, both the presence of others (Grenard et al., 2013; Toumpakari et al., 2019) and higher degree of interpersonal problems (Ranzenhofer et al., 2014; Shingleton et al., 2013) were related to unhealthy eating. Research on environmental factors has elucidated locations and physical spaces inside and outside of the home that are related to various eating and dietary intake behaviors which differ across age (Campbell et al., 2018; Mak et al., 2012; Toumpakari et al., 2019).

Mixed results were found with regard to associations between physical activity and sedentary behaviors and eating behavior, which may be due to the type of eating and dietary intake behaviors being examined. For example, snack consumption was related to watching television and using electronic media (Grenard et al., 2013; Soos et al., 2014) while healthy food consumption was related to television being off (Campbell et al., 2018; Mak et al., 2012). In addition, among adolescents, demographic factors moderated associations between sedentary activities and cravings for unhealthy food and drinks (Borgogna et al., 2015).

Physical activity was related to eating and dietary intake behaviors, but associations differed across studies (Grenard et al., 2013; Marx, 2017; O'Connor et al., 2017). However, physical activity was primarily associated with unhealthy eating and drinking behavior. Further, among children in organized sports, there was a greater likelihood of fast food consumption on games days opposed to other days suggesting that the context of the activity may matter as well (Marx, 2017). The experiences and behaviors of caregivers were related to the eating and dietary intake behaviors of children and adolescents. As would be expected, research has shown that mothers and their children were concordant in their eating and dietary intake behaviors (Dunton et al., 2017). Further, mother's momentary ability to cope with stress was associated with their child's subsequent unhealthy food intake (Mason et al., 2019).

3.3. Future directions

While the extant EMA research on eating and dietary intake behaviors among children and adolescents has revealed some clear within-subjects factors associated with behaviors, there are a number of mixed findings. After reviewing the literature, several areas for future research were formulated, which may lead to increased clarity of how contextual factors are related to eating and dietary intake behaviors in children and adolescents. These include (1)

timing, (2) measure choice, (3) individual difference and contextual factors, and (4) developmental context.

Timing.—Mixed results found in the literature may be related to the timing of EMA reporting and the EMA signaling structure. For example, some studies examined concurrent associations between factors and eating while others examined time-lagged associations. For studies examining time-lagged relationships, the time in between EMA prompts could differ widely depending on the EMA signaling structure. Because the link between contextual factors and eating is a highly dynamic process (Kockler, Santangelo, & Ebner-Priemer, 2018), it may be necessary to examine associations between contextual factors and eating across shorter time-frames in order to reach significance. Further, there may be important differences between how contextual factors act as antecedents and consequences of eating (Smyth et al., 2007).

Micro-temporal studies (e.g., repeated assessments across minutes; Intille, Haynes, Maniar, Ponnada, & Manjourides, 2016), studies using complex EMA signaling structures, and passive data collection (e.g., heart rate monitors, eating detectors) are necessary to fully understand the dynamic relations between context and eating (Desendorf, Bassett, Raynor, & Coe, 2014; Kalantarian, Alshurafa, Le, & Sarrafzadeh, 2015; Ranzenhofer et al., 2016). Particularly, smartwatches offer new opportunities for micro-temporal EMA by providing brief but dense prompting across the day (Intille et al., 2016). These novel approaches may offer increased ability to understand the timing of eating and contextual factors.

Measure choice.—Overall studies varied widely in measures used to assess eating and dietary intake behaviors. This is consistent with the larger EMA diet literature, which includes a host of measures and procedures used to assess eating and dietary intake behaviors (Schembre et al., 2018). Future research should consider drawing on and improving upon these previously used protocols when designing studies. Further, EMA eating measures that have been validated against 24-h recall of diet among children are particularly valuable (Costello, Deighton, Dyson, McKenna, & Jones, 2017; O'Connor, Ke, Dzubur, Schembre, Dunton, & 2018). Also, novel measures have the potential to provide useful data on eating behavior including food photos (Costello et al., 2017) and passive monitors (e.g., bite counters, wearables; Desendorf et al., 2014; Kalantarian et al., 2015). In addition to actual eating behaviors, future research should include measures of appetite, food cravings, and food thoughts in children and adolescents as these are salient, yet understudied momentary factors associated with eating (Grenard et al., 2013).

Individual difference and contextual factors.—There may be unexplored or unmeasured individual difference (e.g., personality, brain structure) and situational/contextual (e.g., food availability, being alone versus with friends) factors that modulate associations between momentary factors and eating and dietary intake behaviors. For example, one reviewed study found that demographic factors moderated the association between sedentary behavior and craving for unhealthy food and drinks (Borgogna et al., 2015), and another study found that individual differences in motivation moderated the daily effect of hedonic hunger on eating (Bejarano & Cushing, 2018). There also may be interactions between momentary contextual factors in predicting eating behaviors (Pearson

et al., 2018). Further, momentary contextual factors associated with eating and dietary intake behaviors may vary depending on where the child is eating (e.g., at home, at restaurant, at school). Also, it may be important to examine mediational relations between contextual factors and eating behaviors. For instance, some research suggests that the mood-behavior link becomes learned through development of an expectancy that eating will relieve negative affect (Pearson, Wonderlich, & Smith, 2015). This demonstrates the utility of studying expectancies as a mediator of the momentary mood-behavior link.

Developmental context.—This review included studies from children of a large span of ages (from 1.5 years to 18 years), which may explain the high degree of mixed findings. The developmental context and age of the group being studied is important to consider in EMA research on eating and dietary intake behaviors. For example, younger children typically rely highly on caregivers for food, and thus it may be important to include caregivers in this research (Savage, Fisher, & Birch, 2007). However, adolescents have increasing autonomy with regard to food intake. Further, as children get older, peer and social factors become increasingly important to examine in relation to eating and dietary intake behaviors as children spend more time eating with friends (Brown, 2004; Mak et al., 2012). Peers may influence eating and dietary intake behaviors through social norms or motives to conform (Salvy, De La Haye, Bowker, & Hermans, 2012). In addition, getting food together with friends may be a social activity (Dunbar, 2017).

Childhood and adolescence are a period where emotional and cognitive development occurs (Saarni, Campos, & Camras, 2008). In addition, functional relationships between contextual factors and eating behaviors may be developing during these periods as well. This could possibly explain the mixed findings that have been uncovered. For instance, the link between mood and eating may be learned across this developmental period, and thus perhaps, mood may not become intertwined with eating until later in adolescence and adulthood.

4. Conclusion

This systematic review synthesized the somewhat heterogeneous literature on the use of EMA to study eating and dietary intake behaviors in children and adolescents. First, this review found that a combination of signal-, event-, and interval-contingent signals would provide the greatest flexibility in studying eating and dietary intake behaviors in children. Second, contextual factors studied in the literature can be grouped into several categories: affect and stress; cognitive factors; social and environment factors; behavioral factors; and caregiver-related factors. Third, there is a high degree of inconsistency with regard to which contextual factors are related to eating behaviors, but cognitive and social factors appear to be among the most consistently related. Fourth, future EMA research needs to consider timing, measure choice, individual differences, contextual factors, and developmental context.

Overall, advances in EMA research on eating and dietary intake behaviors in children and adolescents and elucidation of momentary predictors and mechanisms could lead to the development of new interventions. Traditional public health treatment efforts have typically relied on nomothetic methods, which include attempts to generalize treatments across

persons (Cheung et al., 2017). However, increasingly, idiographic approaches are being considered, which attempt to focus on individuals and tailor interventions to them. For example, just-in-time adaptive interventions and ecological momentary interventions utilize EMA research to inform interventions delivered in individuals' natural environments by targeting salient contextual factors (Heron & Smyth, 2010). These types of interventions could bolster traditional public health treatment efforts by providing tailored assistance for individuals that provide support in the contexts and times where the support is needed.

However, EMA is not without limitations. When developing new studies on eating and dietary intake behaviors in children and adolescents, research should take in to account a number of factors. EMA can be costly and burdensome especially with more complex signaling schemes. Due to this, EMA questions and surveys are typically brief and are not as comprehensive as other measures, which means they may not fully assess constructs of interest. Further, in order to test individual difference and contextual factors as moderators, larger sample sizes are needed at both the within- and between-person levels. Finally, EMA protocols can be complex and need to be tailored for the age group being studied. One possibility is to program EMA to be tailored for different age participants in a study. However, EMA may not always be the best solution for all studies in this area. Researchers should fully consider the benefits and drawbacks to EMA and may consider other paradigms (e.g., laboratory) to answer their questions. In addition, multi-method approaches using EMA and other methods may be even more fruitful for investigating children's eating. EMA typically provides less information about portion size and specific nutritional information. For example, the reviewed studies only looked at whether various foods were eaten but not the amount or nutrients. Therefore, integrating EMA with 24-h recall and laboratory methods may be optimal for understanding contextual factors associated with eating and dietary intake behaviors.

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Fig. 1.
PRISMA flow diagram of paper selection.

Characteristics of reviewed EMA studies examining eating and dietary intake behaviors among children and adolescents.

Table 1

Reference	Sample Characteristics	EMA Protocol	Measures	Findings
Bejarano and Cushing (2018).	50 adolescents (mean age=14.70, SD=1.49, range: 13–18)	Participants answered EMA surveys through a smartphone app for one assessment wave lasting 20 days. Participants were prompted four surveys per day, but only the last survey was used for the current study.	<ul style="list-style-type: none"> Daily hedonic hunger and daily food consumption was collected through the final EMA survey of the day. Autonomous and controlled motivation for eating a healthy diet were assessed through a baseline questionnaire. 	<ul style="list-style-type: none"> Within-person hedonic hunger was positively associated with starchy food consumption. Within-subject hedonic hunger and controlled motivation were positively associated with starchy food consumption, while within-person hedonic hunger and autonomous motivation were negatively associated with fast food consumption.
Campbell et al. 2018	277 mother-toddler dyads (toddler mean age=20.0 months, SD=5.4)	Mothers completed EMA during one assessment wave consisting of a study monitoring period of eight days. During the eight days, questionnaires were randomly prompted on a PDA five to eight times a day.	<ul style="list-style-type: none"> Diet, snack consumption, and home environment related to feeding and physical activity context was assessed through EMA. 	<ul style="list-style-type: none"> Toddlers were more likely to eat snacks when not in a high chair/chair and when eating alone.
Dunton et al. 2017	167 mother and 8- to 12-year-old child dyads (mean=9.6, SD=0.9)	Mothers and children received up to 7 semi-random signals per day over 8 days, excluding time at school.	<ul style="list-style-type: none"> At each prompt, mothers and children reported on their current perceived stress and foods consumed in the past 2 h. 	<ul style="list-style-type: none"> Individual toddlers were more likely to eat snacks when moving around. Children reported more healthy and unhealthy eating on days when their mothers also engaged in more healthy and unhealthy eating, respectively.
O'Connor et al. 2017	175 mother and 8- to 12-year-old child dyads (mean=9.6, SD=0.9)	Mothers and children received up to 7 semi-random signals per day over 8 days, excluding time at school.	<ul style="list-style-type: none"> At each prompt, mothers and children reported on their current activity, sedentary behaviors, and foods consumed in the past 2 h. 	<ul style="list-style-type: none"> Neither children's nor mothers' daily level of stress were associated with children's daily healthy or unhealthy food intake. Children were more likely than their mothers to consume unhealthy foods in 2 h EMA windows that included physical activity but not sedentary screen activity. Children and mothers did not differ in likelihood of consuming healthy foods during 2 h EMA windows with sedentary screen activity or physical activity.
Mason et al. (2019)	202 mother-child dyads (child mean age=9.60, SD=0.92, range: 8–12)	Mothers and children received up to 7 semi-random signals per day over 8 days, excluding time at school.	<ul style="list-style-type: none"> Measures included, negative affect, positive affect, ability to cope with stress, and food intake. 	<ul style="list-style-type: none"> Mothers' momentary ability to cope with stress predicted their own and their child's pastries/sweets intake and their own fries/chips intake. Children's momentary ability to cope with stress predicted their own pastries/sweets intake. There were no associations between positive affect or negative affect with food intake.

Reference	Sample Characteristics	EMA Protocol	Measures	Findings
Goldschmidt et al. 2018	40 male and female youth (55% female) aged 8–14 years old with overweight or obesity (mean=11.2, SD=1.9)	EMA recordings were completed after any type of eating behavior; before bedtime; and at 3–5 semi-random times throughout the day. Signaled prompts occurred every 2–3 h between 8:00 a.m. and 9:00 pm on the weekends, and between 7:00 and 8:00 a.m., 3:00 and 4:00 pm, and 6:00 and 7:00 pm on weekdays, but not during schooltime.	<ul style="list-style-type: none"> At prompts, participants completed measures of overeating, LOC eating, cravings, hunger, food hedonics, electronics use, influence of others on eating, affect, stressful events, body and weight concerns, and interpersonal problems. 	<ul style="list-style-type: none"> Greater than usual perceived palatability of food being consumed (i.e., food hedonics) was associated with greater LOC severity
Grenard et al. 2013	158 urban adolescents aged 14–17 (mean age=15.98, SD=1.03)	Event-contingent recordings were used whenever participants drank or ate something. Participants also received random prompts (2 times on weekdays after school and 4 times on weekend days).	<ul style="list-style-type: none"> Food consumption was measured through food categories and sub-categories for all self-reported food and drinks. 	<ul style="list-style-type: none"> There were no within- or between-subjects associations between negative affect, stressful events, hunger, craving, social influence, or electronics use and LOC eating or overeating. Sweet drink consumption was associated with exercising, feeling lonely, feeling energetic, craving a drink or snack, being with friends, and being exposed to food cues.
Borgogna et al. (2015)	158 urban adolescents aged 14–17	Event-contingent recordings were used whenever participants drank or ate something. Participants also received random prompts (2 times on weekdays after school and 4 times on weekend days). Participants completed end of day recordings before bedtime.	<ul style="list-style-type: none"> Location, social setting, family influence, current mood, activities, appetite/craving, binge eating, daily stress level, daily food availability in the home, and physical activity were measured through EMA. 	<ul style="list-style-type: none"> Sweet snack consumption was related to watching television and using electronic media, feeling bored, craving a drink or snack, being at school, and being exposed to food cues. Salty snack consumption was associated with craving a drink or snack, being at school, being with co-workers, and being exposed to food cues. Neither aggregate positive nor negative affect were related to unhealthy eating variables. Non-Hispanic adolescents showed stronger associations between television exposure and cravings for sweet snacks, salty snacks, and sweetened drinks.
Hilbert et al. (2009)	Children aged 8–13 years with loss of control eating ($n = 59$), and 59 matched children without loss of control eating.	The study used a combined random- and event- sampling protocol for four days (two weekdays and two weekends), except during school hours. Random-	<ul style="list-style-type: none"> Measures included food intake, loss of control eating, mood, hunger and satiety, and eating disorder-specific cognitions. 	<ul style="list-style-type: none"> Being Hispanic was associated with stronger associations between phone messaging and cravings for sweet snacks, salty snacks, and sweetened drinks. Males showed stronger associations between video game use and salty snack cravings. Loss of control eating episodes led to significantly greater intake of energy, particularly from carbohydrates, than regular meals of children with and without loss of control eating.

Reference	Sample Characteristics	EMA Protocol	Measures	Findings
	Mean age = 10.77 years; SD = 1.46).	signals involved a research assistant calling the child, and event-sampling involved the child calling the research assistant immediately after an eating episodes.		<ul style="list-style-type: none"> • Loss of control eating episodes were preceded and followed by cognitions about food/eating and body image. • Negative affect did not predict loss of control eating. • In children with loss of control eating, less happiness preceded both regular and loss of control eating episodes. • Diagnosis of anorexia nervosa was associated with more aversive tension.
Kolar et al. (2016)	N = 40, 20 female adolescents with anorexia nervosa in outpatient treatment (mean age = 16; SD = 1.55) and 20 healthy adolescents aged 12–19 years (mean age = 15.9; SD = 1.95)	Participants completed two days of EMA on weekdays. They received a signal every hour over the two days.	<ul style="list-style-type: none"> • Participants completed measures of aversive tension and food intake events. 	<ul style="list-style-type: none"> • Food intake was associated with aversion tension in women with anorexia nervosa, but not healthy controls. • Aversive tension reduced after food intake in girls with anorexia nervosa. • 73% of eating episodes took place at home and 31% occurred with parents only.
Mak et al. (2012)	N = 642 children between 1.5 and 10 years old (mean age = 5.3; SD = 2.8)	Parents were given instructions to recall all caloric intake of their child over four consecutive days using unweighed food diaries. Days were divided into seven windows (6–9am, 9–12pm, 12–2pm, 2–5 pm, 5–8pm, 8–10 pm and 10 pm–6am).	<ul style="list-style-type: none"> • For every eating episode, parents were asked to indicate where their child was, who the child was with, whether the TV was on, whether the child was eating at a table, and the time of consumption. 	<ul style="list-style-type: none"> • Frequency of eating alone and with friends increased with age. • Children aged 1.5–3 years old were more likely to consume fruit at care outside home compared to home. • Children aged 4–6 years old were more likely to consume fruit and vegetables at school compared to home. • Children aged 1.5–3 years old were more likely to consume fruit with friends and with a carer and other children/others compared to with parents. • Children aged 4–6 years old were more likely to consume fruit and vegetables with friends compared to at home. • Children of all ages were more likely to eat vegetables when the TV was off than on and at a table than not at table. • Youth athletes consumed significantly more fast food on game days than practice days or non-sport days but there were no differences in consumption of sports drinks, sweets, sport/energy bars, fruit, or vegetables.
Marx (2017)	N = 29 parents of youth athletes ages 8–14 (mean age = 11.1; SD = 2.1)	Parents were contacted 12 times throughout the spring season and asked to respond to a series of questions about	<ul style="list-style-type: none"> • Parents completed measures of child's consumption of sugary drinks, fast food, sweet/pastries, 	

Reference	Sample Characteristics	EMA Protocol	Measures	Findings
O'Reilly et al. (2015)	110 children (mean age = 11.0 ± 1.2 years, 52.5% male, 30.1% Hispanic/Latino)	their child's eating behavior that day at 7 pm Random EMA prompts were given for a full or partial day over a four-day period from Friday at 4:00pm through Monday at 8:30pm, excluding school hours.	granola/protein bars, fruits, vegetables, and snacks. • EMA measures included positive affect, negative affect, physical energy, and physical fatigue.	<ul style="list-style-type: none"> • Parents reported that their child consumed fast food on almost 70% of game days, compared to about 30% on practice and non-sport days. • Greater usual fiber intake was related to higher mean positive affect, lower variability of negative affect, and higher variability of physical fatigue. • Lower usual glycemic load of diet was associated with lower variability of negative affect. • Lower usual added sugar intake was associated with higher average physical energy and lower variability of negative affect.
Ranzenhofer et al. (2014)	Thirty adolescent girls with overweight or obesity (Age: M = 14.92, SD = 1.54 y; 60.0% African American) who reported at least two LOC episodes in the past month	Participants completed 3–5 signal-contingent ratings each day. Girls were not signaled during school time. Participants completed event-contingent recordings of eating episodes. The protocol lasted two weeks.	• Measures included loss of control eating, affect, and interpersonal problems.	<ul style="list-style-type: none"> • Within-subjects interpersonal problems predicted loss of control eating.
Ranzenhofer et al. (2016)	17 adolescent girls with overweight or obesity who reported engaging in at least two episodes of loss of control eating during the prior month (mean age = 14.77, SD = 1.55, range: 12–17)	For two days, adolescents completed signal- contingent recordings across the day and event- contingent recordings before and after eating, except while at school. Participants also wore a Holter monitor across the two days.	<ul style="list-style-type: none"> • Loss of control eating and posture were assessed during each signal-contingent and event-contingent recording. • Heart rate and heart rate variability were measured by Holter monitor. • EMA recordings included assessments of self-destructive thoughts and contextual factors. 	<ul style="list-style-type: none"> • Negative affect was unrelated to loss of control eating. • Higher momentary heart rate and lower heart rate variability in the 30-min window prior to eating were associated with loss of control eating.
Shingleton et al. (2013)	30 adolescents ($n = 26$ female; mean age = 17; SD = 1.9) with a history of non-suicidal self-injury (NSSI)	Event-contingent recordings required participants to complete a survey whenever they experienced self-destructive thoughts/behaviors. In addition, there were two signal-contingent recordings (one at midday and one at end of day). The EMA measures lasted around 14 days		<ul style="list-style-type: none"> • Seventy-nine percent of binge eating and/or purging thoughts co-occurred with other self-destructive thoughts. • Binge eating and/or purging thoughts occurred primarily while eating. • Adolescents were more often with friends/peers than alone or with family when having binge eating and/or purging thoughts.

Reference	Sample Characteristics	EMA Protocol	Measures	Findings
Soos et al. (2014)	812 secondary-school students from Hungary, Romania, Slovakia, the United Kingdom, and China (mean age = 15.6, SD = 1.0, range: 11.9–17.9)	Participants completed free time diaries for one assessment wave consisting of three weekdays; participants self-reported their behavior every 15 min.	<ul style="list-style-type: none"> • Portions of sweets and crisps that were consumed, behaviors, locations, and social contexts were collected through diaries. 	<ul style="list-style-type: none"> • Worry, pressure, perceived criticism, and rejection/hurt commonly occurred along with binge eating and/or purging thoughts. • Higher levels of TV viewing were associated with more snack food consumption
Toumpakari et al. (2019)	884 adolescents aged 11–18 years	Participants completed one assessment wave consisting of a four-day food diary recording and EMA.	<ul style="list-style-type: none"> • Dietary assessment was collected through food diaries. • Information on where and with whom the eating context occurred was collected through EMA. 	<ul style="list-style-type: none"> • Eating at “eateries” was associated with the largest non-core energy intake, with intake more than double the amount eaten at home and eating with family and friends was the social context with the highest non-core energy intake compared to eating alone.

Table 2

Summary of findings of studies.

Study	Type of Study	Design	Sample Size	Age	Sample Type	Signal Scheme	Eating Measure	E/M Device	Other devices
Bejarano and Cushing (2018)	Observational	Single Wave	50	14.7	Adolescents	Interval	Normal	Smartphone	Accelerometer
Campbell et al. (2018)	Observational	Multi Wave	277	1.7	Children	Random	Normal	PDA	Accelerometer
Dunton et al. (2017)	Observational	Multi Wave	202	9.6	Children	Random	Normal	Smartphone	Accelerometer
Mason et al. (2019)									
O'Connor et al. (2017)									
Goldschmidt et al. (2018)	Observational	Single Wave	40	11.2	Both	Multiple	Pathological	Smartphone	Accelerometer
Grenard et al. (2013)	Observational	Single Wave	158	16.0	Adolescents	Multiple	Normal	PDA	–
Borgogna et al. (2015)									
Hilbert et al. (2009)	Observational	Single Wave	118	10.8	Both	Multiple	Multiple	Smartphone	–
Kolar et al. (2016)	Observational	Single Wave	40	16.0	Adolescents	Interval	Eating versus not	Smartphone	–
Mak et al. (2012)	Observational	Multi Wave	642	5.3	Children	Interval	Normal	Paper diaries	–
Marx (2017)	Observational and Treatment	Multi Wave	29	11.1	Both	Interval	Normal	Smartphone	–
O'Reilly et al. (2015)	Observational	Multi Wave	110	11.0	Children	Random	Normal	Smartphone	Accelerometer; GPS
Ranzenhofer et al. (2014)	Observational	Single Wave	30	14.9	Adolescents	Multiple	Pathological	PDA	–
Ranzenhofer et al. (2016)	Observational	Single Wave	17	15.0	Adolescents	Multiple	Pathological	PDA	Holter monitor
Shingleton et al. (2013)	Observational	Single Wave	30	17.0	Adolescents	Multiple	Pathological	PDA	–
Soos et al. (2014)	Observational	Single Wave	812	15.6	Both	Interval	Normal	Paper diaries	–
Toumpakari et al (2019)	Observational	Multi Wave	884	–	Adolescents	Multiple	Normal	Paper diaries	–

Note. GPS=global positioning system.