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Review

A developmental model of emotional eating

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ABSTRACT

Over- and under-eating in response to subjective emotional states (emotional eating) are well described behaviours that are thought to emerge early in life. Research and theory have proposed that individual characteristics and environmental factors (e.g. parental feeding practices) both contribute to the development of emotional eating. However, the mechanisms underlying this development are poorly understood. Here, we review relevant literature that pertains to factors and processes involved in the development of emotional eating and propose a comprehensive model suggesting how emotional eating develops throughout infancy and childhood. Within the model, we describe the biological and environmental factors that could impact a child's probability for emotional eating. We identify key mechanisms that may influence how these factors lead to emotional eating, such as interoceptive processing, emotion regulation and appetite self-regulation. We put forward the idea that emotional eating is a context dependent behaviour, with the extent of emotional eating likely influenced by contextual factors operating in conjunction with key mechanisms. Lastly, we offer potential pathways through which emotional eating develops as a learnt behaviour. The proposed model provides a comprehensive explanation that considers the complexity of emotional eating behaviours and generates novel ideas for future research.

Introduction

Feeding and eating are relational acts embedded in the context of connection, where food and relationship come together. Infants rely on their caregivers to provide nurturance and create the conditions for survival and healthy development. In this sense, emotional and physical nourishment are deeply interconnected. The brain-gut crosstalk (i.e. the bidirectional signalling between the central and enteric nervous systems) has been implicated not only in the maintenance of gastrointestinal homeostasis, but also with emotional, motivational and cognitive functions (Mayer, 2011). Therefore, it is not surprising that subjective emotional states can influence feeding and eating behaviour, and vice versa. However, how and why certain individuals become more susceptible to these influences remain open questions. In this review, we propose a novel model of emotional eating by discussing the mechanisms and factors implicated in its development.

Emotional eating (EE[1]) is a complex behaviour observed in both young children and adults, whereby changes in eating occur in response to subjective emotional states, rather than to physiological hunger or satiety (González et al., 2022). Predictably, EE has been linked with health outcomes such as weight gain and overweight (Braet et al., 2008; Braet & Van Strien, 1997; van Strien, Herman, &

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[1] Abbreviations: EE = Emotional Eating, HED = High Energy Dense, LED = Low Energy Dense, OFC = Orbito-Frontal Cortex, EAH = Eating in the Absence of Hunger.

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Verheijden, 2009). Yet, it may also play a role in promoting or maintaining poor dietary habits, such as consuming excess energy, valuing high energy dense (HED) over lower energy dense (LED) foods, and not maintaining a balanced and varied diet (Michels et al., 2012; Nguyen-Michel, Unger, & Spruijt-Metz, 2007). To date, models of EE have focused on adulthood, describing and explaining associated behaviours (Macht, 2008). However, there is little theoretical work detailing the development of EE, especially in the early years of life. Infancy and toddlerhood are crucial developmental periods where children learn to eat and learn the value of food. Concurrently, children undergo rapid neurodevelopment of subcortical and prefrontal brain systems (Hodel, 2018) that oversee motivation, reward and executive functions, all of which are critical for processes and mechanisms that have been associated with EE later in life (e.g. high dietary restraint, poor interoceptive processing, alexithymia, emotion dysregulation and a reversed hypothalamic pituitary adrenal (HPA) stress axis; see van Strien, 2018 for a review). Therefore, there is potential for EE behaviours to either emerge or develop from an early age as a result of brain changes and interactions with the environment.

EE is characterised by two main behaviours, emotional overeating and undereating. Studies using questionnaire based parental measures indicate that emotional undereating may be the more prevalent behaviour in child samples (Messerli-Bürgy et al., 2018), yet research has often focused on emotional overeating, potentially due to ease of measurement compared with undereating, or clearer links with overweight and obesity outcomes. Interestingly, both emotional under and over-eating tend to be positively correlated (Domoff, Miller, Kaciroti, & Lumeng, 2015; Wardle, Guthrie, Sanderson, & Rapoport, 2001), although it is not known whether they share a common aetiology. Incidences of emotional overeating behaviours have been shown to increase as children age (Ashcroft, Semmler, Carnell, Van Jaarsveld, & Wardle, 2008), with more distinct behavioural patterns across childhood (Derks et al., 2019). Emotional overeating has previously been described as occurring in response to mild negative emotions, in-between meals, in the absence of hunger and with HED, palatable foods that are high in fats and sugar (González et al., 2022). Conversely, emotional undereating may occur in response to more intense, specific or prolonged emotional states or stressors (Robbins & Fray, 1980; Wallis & Hetherington, 2009). In the literature, emotional over and under-eating have been vaguely defined as eating more or less respectively in response to emotions (Bjørklund, Wichstrøm, Llewellyn, & Steinsbekk, 2019; Wardle et al., 2001). For clarity, we define these terms as eating more (or less) energy than usual at a particular eating occasion (or over time for undereating) as a response to subjective emotional states. It is important to note that whereas overeating can occur at any time (even outside of usual eating times and settings), undereating must occur either during usual eating times or over a period of time. This is because if not, the behaviour would be best described as a usual satiety response in-between meals. Definitions of fundamental terms used throughout the paper are provided in Table 1.

In Fig. 1, we present a model illustrating how EE might develop in healthy children. We have divided the model into three constituent parts (A, B, and C) to clearly highlight the different processes involved in the development and occurrence of EE. Part A illustrates factors that create a child's probability (or likelihood) for EE. This is based on current literature demonstrating trait-based EE behaviours, and observations from other literatures illustrating potential mechanisms that may have an impact on the development of EE (e.g. appetite self-regulation, interoceptive processing, emotion regulation, etc.). We acknowledge that the factors in part A may have age-dependent, as well as cross-lagged effects, which may in turn affect the development of EE. These factors will not only have different influences on EE as the child ages, but we would also expect that the way these factors interact (as well as the strength of relationship between factors) will be individual to children's development of EE. Part B introduces the context dependent nature of EE. This illustrates that without the context of an emotion and food availability, EE cannot be an adequate behavioural response. As there is little evidence explaining how contextual factors may influence the likelihood of EE to occur, new ideas are presented for future research to conceptualise EE as not only a trait, but also a state-like behaviour that can change depending on the context and circumstances within which eating occurs. Lastly, part C places a large emphasis on learning. Here, we propose that learning mechanisms may affect whether EE will occur in future similar contexts and that, through feedback loops, learning may influence the initial factors that formed a probability for EE. In the following sections of this paper, we explain each part of the model in detail.

Factors affecting children's probability for emotional eating

Parts A of Fig. 1 describes how a probability for EE develops. We suggest that child characteristics and environmental factors play a large role in determining children's probability for EE. Many factors within these general categories have been shown to relate to EE individually (e.g. Barth et al., 2020; Farrow, Haycraft, & Blissett, 2015), yet their relationships are often complex, interacting and interrelating in ways that can be both protective of, or increase the risk of, EE. Additionally, each factor may have different levels of influence on EE behaviours at different ages and developmental stages (Fig. 1 part A). This section is not a comprehensive or exhaustive review of the literature, but rather a summary of the key findings from which our model was developed.[2]

It is thought that having a genetic predisposition to obesity can affect weight status through behavioural pathways such as

[2] Though most studies have addressed the question "what predicts EE?", it is also important to note that there are many protective factors that could decrease EE by the child. For example, parent mindful eating is associated with less child EE (Brantley, Knol, & Douglas, 2022). Structure and routines, such as eating meals more frequently as a family and having a structured meal setting also negatively correlated with emotional under and over eating (Jansen, Mallan, Nicholson, & Daniels, 2014). This may be due to having less opportunity to eat outside mealtimes (in response to states other than hunger and satiety, such as emotions) or structured mealtimes having a positive influence on children's relationships and attitudes with, and towards, food. Additionally, it might be assumed that the counterparts to the risk factors discussed in this section may have protective effects for EE behaviours (e.g. parental use of positive feeding practices, low negative affectivity or reactive temperaments, etc.). However, data focusing on specific protective factors of EE is needed to confirm these hypotheses.

Table 1
Definitions of key concepts used throughout this paper.

Concept	Definition
Emotional eating	Eating (over) or not eating (under) different types and amounts of food as a response to either positive or negative emotional states (Crockett, Myhre, & Rokke, 2015; Evers, Adriaanse, de Ridder, & de Witt Huberts, 2013).
External eating	Overeating characterised by high cue reactivity to food cues (sight, smell, taste, etc.), regardless of physiological hunger or satiety cues (Harrist, Hubbs-Tait, Topham, Shriver, & Page, 2013; Van Strien, Frijters, Bergers, & Defares, 1986).
Self-regulation	A broad term referring to regulation by the self (not just of the self) – a process of determining a desired end state and performing goal directed behaviours to move toward it, whilst monitoring progress toward the goal (Carver & Scheier, 1998).
Appetite self-regulation	A process that makes changes to food and energy intake through the interaction of biological/physiological systems with cognitive, emotional, social and behavioural influences (Russell & Russell, 2021).
Emotion regulation	A process that effects changes in the occurrence, valence, intensity, duration, and timing of subjective emotional states to the environment, across multiple (physiological, neural, cognitive, behavioural, and subjective) domains (Cole & Hollenstein, 2018).
Interoception	The ability to sense, interpret and integrate signals about the physiological condition of the body (e.g. states such as heart rate, bladder distension and hunger) (Craig, 2002; Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004).

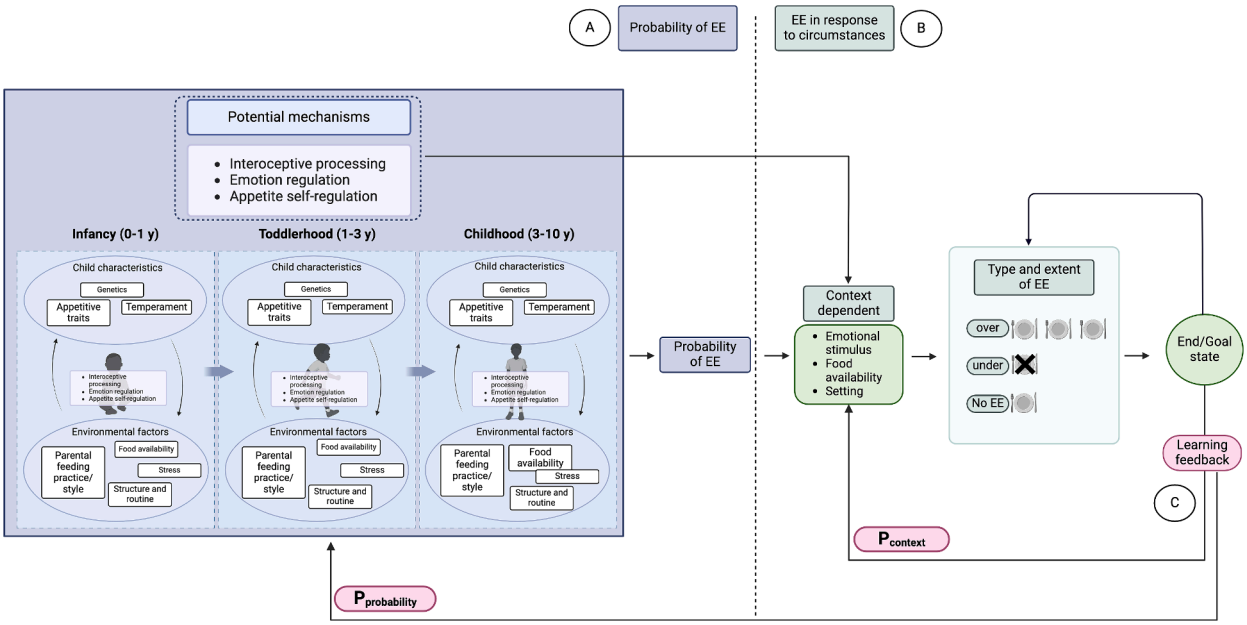

Fig. 1. A model of the development of EE. The figure suggests how child and environmental factors combine with certain mechanisms to create a probability for EE (part A). These factors are age, and developmental stage, dependent and as such their contribution to EE may be more or less important at different time points (highlighted in the figure by the use of bigger and smaller fonts, respectively). The notion of mechanisms of change is, by definition, time-dependent (Benton, 2022). Thus, our potential mechanisms are also included under developmental time. The probability for EE is then brought to each circumstance where EE may occur (part B), influencing the likelihood of EE occurring. However, each occasion where EE is possible is dependent on contextual factors that may influence the extent of EE. Each experience offers learning potential (part C), feeding back to future similar circumstances ($P_{context}$) or the factors that create a probability for EE ($P_{probability}$), consequently affecting future EE behaviours. The figure was created using Biorender.com.

uncontrolled, external or emotional eating (Konttinen et al., 2015). It may then be inferred that such a genetic predisposition could underlie EE. However, evidence across developmental age groups is mixed. Twin studies examining the shared genetic and environmental influences on EE of 16-month-olds and 5-year-olds suggest that heritability of EE is low (up to 10 %), whilst the environment (such as the child's home setting) plays a much stronger role (Herle, Fildes, Rijsdijk, Steinsbekk, & Llewellyn, 2018). Yet, heritability estimates for emotional overeating have been found to be moderate to high for 10-year-old children (Warkentin, Severo, Fildes, & Oliveira, 2022) and adults (Konttinen, 2020). Although, emotional undereating at 10 years was largely determined by environmental factors (Warkentin et al., 2022). Similarly, studies examining specific genetic markers of EE (e.g. high prefrontal DRD4 gene expression) found that children with high expression of the target genes exhibited more, or less, EE dependent on how positive their environment was (Barth et al., 2020). Many environmental variables were accounted for including maternal mental health, household income, family functioning, and marital strain – illustrating a number of environmental influences on the development of EE. Together, these studies suggest an increasingly important role of genetics with age and specifically when interacting with environmental factors. It may be that genetic influences become more apparent in behaviour when children are able to make their own choices and have more control over their environment (Herle, et al., 2018).

Whilst genetics alone may not play a primary role in EE at young ages, child temperament is a promising area of research that could explain some individual differences. For example, 4-to-6-year-old children's higher reactive temperament (negative affectivity and impulsivity) is linked with higher food consumption in response to stressors (Ohrt, Perez, Liew, Hernández, & Yu, 2020). Negative affectivity has also been positively associated with child EE cross-sectionally (e.g., Holley et al., 2020; Messerli-Bürgy et al., 2018), and other studies have found longitudinal associations between temperament and EE. Steinsbekk et al. (2016) found that high negative affectivity at 4 years of age predicted child EE at 6-, 8- and 10-years of age. The same research lab also reported longitudinal associations between child's effortful control and EE: lower effortful control at 6 years was prospectively associated with increased EE at 8 years (Steinsbekk et al., 2020).

Among children's individual differences, appetitive traits are additionally noted as contributing to EE. In particular, food approach behaviours (i.e., eating behaviours that are associated with a heightened drive towards food) such as food responsiveness and enjoyment of food, have been associated with greater EE during childhood (Vandeweghe et al., 2016). High food responsiveness at age 6 was correlated with greater EE tendencies both cross-sectionally and longitudinally at age 8 (Steinbekk et al., 2016). Food approach tendencies were also associated with 6-to-11-year olds' EE, and these associations persisted longitudinally one year later (Koch & Pollatos, 2014).

While the above research suggests that EE may be related to the child's individual characteristics, studies have also pointed to the role of parent behaviours in contributing to the development of EE. There is a wealth of literature to suggest that less responsive feeding practices may undermine the child's ability to appraise their hunger and fullness and lead to the development of non-intuitive eating behaviours (i.e., eating for reasons other than internal sensations of hunger and fullness). Importantly, these associations seem to be established from infancy and persist across childhood. For example, feeding to soothe at 6 months has been prospectively associated with more food responsiveness and EE at 12 months (Temmen et al., 2021; Schneider-Worthington et al., 2022). Parental emotional feeding has been associated with greater EE during childhood (e.g., Braden et al., 2014; Powell et al., 2017; Rodgers et al., 2013; Steinsbekk et al., 2018; Tan & Holub, 2015). Similarly, parental reward feeding at 4 years has been found to predict child EE at 9 years (Jansen et al., 2020), and restrictive feeding has been associated with greater toddler EE cross-sectionally (Rodgers et al., 2013).

Yet the associations between child characteristics, environmental factors (such as parental feeding practices), development, and EE are more complex than initially thought. Temperament has been associated with specific parental feeding practices, leading to proposals that the relationships between emotional feeding and EE may be reciprocal. Recent research by Schneider-Worthington et al. (2022) found that perceived infant surgency/extraversion and negative affectivity were associated with feeding to soothe as early as 3–5 months of age. In a study by Steinsbekk, Barker, Llewellyn, Fildes, and Wichstrøm (2018), higher negative affectivity of the child was also found to predict emotional feeding by the parent. Further experimental studies support these ideas, as children were likely to consume more energy in response to an emotional state when parents reported use of food as a reward and food restriction practices (Farrow et al., 2015), or feeding to regulate their child's emotions (Blissett, Haycraft, & Farrow, 2010). Similar complex relationships have been replicated in numerous studies (e.g. Bjørklund et al., 2019; Kininmonth et al., 2023; Stifter & Moding, 2018; Stone, Blissett, Haycraft, & Farrow, 2022). Further research with adolescents may bring this section of interrelations and development full circle, suggesting that genetic alleles of the child may moderate the effect of parental feeding practices on EE behaviours (van Strien, Snoek, van der Zwaluw, & Engels, 2010). However, whilst this body of research illustrates that child temperament, parental feeding, and EE all relate, their developmental pathways and exact mechanisms underlying EE behaviours are not well understood. It is possible that the relationships between child temperament, parental feeding and EE may develop over time, and interact with developmental processes (e.g., executive functions) or environmental factors (e.g., food availability, structure and routine) that would also impact on a child's ability to make decisions about their food intake. Due to these reciprocal relationships between child, parent and environment, instead of focusing on one or two factors that might influence the development of EE, we propose that these factors interrelate to create an overall probability for EE that is specific to the individual child, and that may develop and change over time.

Potential mechanisms of emotional eating

Child and environmental factors may be predictive of EE or a probability for EE, yet they cannot on their own affect whether EE will occur. We suggest that there are various mechanisms that might facilitate their effects on EE, all of which are under-researched with regards to its development. In this section, we will focus on the mechanisms of interoceptive processing, emotion regulation and appetite self-regulation (see Fig. 1 part A), yet we recognise that other potential mechanisms not mentioned in the current model may also influence a probability for EE. For example, Macht and Simons (2011) detail physiological mechanisms related to EE including serotonin increase, endocrine effects and energy increase improving mood. Conversely, understanding of the mechanisms involved in emotional undereating are lacking, with the exception of undereating as a biological response to stress (Sominsky & Spencer, 2014). Our focus on interoceptive processing, emotion regulation and appetite self-regulation for the proposed model is twofold: first, research and theory have shown that these processes are strongly intertwined. For example, impairments in interoceptive processing are associated with emotion dysregulation (Füstös, Gramann, Herbert, & Pollatos, 2013; Pollatos, Matthias, & Keller, 2015) and difficulties in emotion regulation are linked with poor appetite self-regulation and a greater tendency to overeat (Crockett et al., 2015; Evers, Marijn Stok, & de Ridder, 2010; Shriver et al., 2019; van Strien & Ouwens, 2007). Second, evidence from neuroimaging studies suggest that interoceptive, emotional, and appetite self-regulation processing occur in largely overlapping brain structures. The neuroanatomical overlap between interoception and emotional and affective experience has been extensively reported in the literature (Barrett & Simmons, 2015; Craig, 2016; Critchley, 2005). In particular, the insula and anterior cingulate cortex have been implicated in both interoceptive and emotional processing (Craig, 2008; Ernst et al., 2014). The role of the insula in appetite self-regulation has been demonstrated by neuroimaging studies in humans (Hébert-Seropian et al., 2021; Malik, McGlone, Bedrossian, & Dagher, 2008;

Wright et al., 2016) as well as findings in rodents which have shown its involvement in processing motivationally relevant cues differently depending on internal states (i.e. whether one is hungry or full), suggesting top-down control of eating behaviour (Livneh et al., 2017). Importantly, the insular cortex is structurally and functionally connected to the orbitofrontal cortex (OFC), which encodes reward values in the brain. Human and animal studies have shown that the OFC is involved in eating behaviour through the process of assigning reward values to food, which influences behavioural decisions (Gutierrez, Carmena, Nicolelis, & Simon, 2006; Jennings et al., 2019; Kringelbach & Rolls, 2004; Mora, Avrith, Phillips, & Rolls, 1979). The OFC is also thought to play a role in emotion regulation (Bechara, Damasio, & Damasio, 2000; Ursu, Clark, Stenger, & Carter, 2008) and in the processing of interoceptive signals (Craig, 2002; Khalsa et al., 2018). The links that exist between interoceptive processing, emotion regulation, and appetite self-regulation raise the questions as to whether, and to what extent, interoception might underlie the development of regulatory abilities (emotion and appetite). Conceptually, it can be argued that the development of the abilities to sense and interpret internal signals (e.g. a racing heartbeat or a rumbling stomach), which pertain to interoception, are necessary to be able to regulate these signals (Allen & Friston, 2018; Barrett & Simmons, 2015; Pezzulo, Rigoli, & Friston, 2015; Seth, 2013) (see also '*Achieving end (goal) states and feedback for EE*'). In the present paper, we describe each of these mechanisms separately without delving into their interactions, but we acknowledge that the question of what is special (if anything) about interoception, and what is its functional role, remains open for future research and theory to directly address (see also Quigley, Kanoski, Grill, Barrett, & Tsakiris, 2021).

These mechanisms will be first described here as traits that have an additive effect on the probability for EE. Further into the model we will see that the mechanisms of interest also have state like effects in different situations where EE may occur. Whilst there is currently little direct evidence to support the roles of these mechanisms in the development of EE, we put forward ideas regarding what might be happening based on the available developmental literature and literature with older children, adolescents, and adults. Associations are also suggested between each mechanism and the child and environmental factors discussed in *'Factors affecting children's probability for EE'*.

Interoceptive processing

Interoception (see Table 1 for definition) plays a foundational role in the continuous regulation of physiological processes, encompassing heart rate, body temperature, itch, pain, and other bodily sensations. This mechanism operates through complex feedback and feedforward loops, establishing connections between the brain and body, thereby facilitating the prediction and regulation of future bodily states (Petzschner, Garfinkel, Paulus, Koch, & Khalsa, 2021). Converging evidence for the role of interoception in eating behaviour comes predominantly from the adult literature, which has largely focused on eating disorders and obesity (see Herbert, 2021 for a review). For example, in the context of obesity, attenuated sensitivity to internal sensations has been associated with higher BMI (Herbert & Pollatos, 2014; van Dyck et al., 2016). van Dyck et al. (2016) using a water load test showed a positive association between BMI and drunk water volume until feeling satiated, suggesting that hyposensitivity to satiety cues may be implicated in weight status (see Arrouk et al., 2017 for similar findings in children). Additionally, children with overweight are more hyposensitive to cardiac cues than children with normal-weight. Only in children with overweight, interoceptive hyposensitivity seems to precede emotional and external eating behaviours (Koch & Pollatos, 2014). However, it has also been proposed that hypersensitivity to hunger signals may increase eating through heightened reward value of food stimuli and interactions with inhibitory control to influence eating behaviour (Herbert, 2021). In the context of EE, efficient interoceptive abilities are critical for identifying, interpreting and discriminating internal sensations (Herbert, Blechert, Hautzinger, Matthias, & Herbert, 2013; Murphy, Brewer, Catmur, & Bird, 2017). For example, inaccurate interpretation of changes in bodily states (e.g. am I hungry or angry?) could promote confusion between satiation and emotions, which may lead to the consumption of food in response to subjective emotional states. As such, interoceptive abilities and emotion regulation (see 'Emotion regulation') have been identified as two critical mechanisms for EE and obesity in adult research – highlighting again their significant link in explaining a probability for EE. Indeed, adults with low interoceptive accuracy are more likely to struggle with regulating their emotions and have a higher inclination to eat based on emotional rather than physiological cues (Füstös et al., 2013; Herbert et al., 2013). Similarly, adults with obesity and a tendency to EE have increased emotion regulation difficulties and low interoceptive awareness (Dalrymple, Clark, Chelminski, & Zimmerman, 2018). More recently, Willem et al. (2021) demonstrated that deficits in interoceptive sensibility (the ability to notice, observe, and describe bodily sensations) in individuals with obesity were associated with higher EE through deficits in the ability to trust and rely on bodily states and higher emotion dysregulation. These findings suggest that deficits in one's ability to trust, consider useful or use internal bodily signals (what Willem et al., 2021 labelled 'interoceptive reliance') might increase susceptibility for EE in adults.

Despite accumulating evidence suggesting the role of interoceptive abilities in EE, developmental research on the topic is lacking. More generally, we still know very little about how interoceptive processing emerges and develops. How do infants learn, for example, to associate a rumbling stomach with hunger and eating? Recent theories have put forward the hypothesis that the caregiver's ability to meet the infant's needs is at the hallmark of infants' ability to maintain homeostasis (Atzil, Gao, Fradkin, & Barrett, 2018; Fotopoulou & Tsakiris, 2017), therefore pointing to the key role of the environment in infants' development of interoceptive processing. It has also been suggested that individual differences in infants' abilities to perceive a change in bodily state and to signal the perceived change to caregivers may be critical for learning to ascribe a meaning to these sensations through caregiver-infant interactions (Filippetti, 2021). Therefore, it may be possible that, for example, if an infant often displays high fussing due to heightened perception of bodily sensations, the caregiver may adjust their responses by taking control or increasing vigilance of the child to avoid the frequent crying. Reiterations of these interactions may lead to the caregiver disregarding the infants' own cues, leaving them unable to appraise the state of their bodies and more likely to misattribute the meaning of changes in internal sensations (Filippetti, 2021). Indeed, there is evidence suggesting that parents whose children often display negative affectivity are more likely to feed the child to reduce tantrums

(Agras, Hammer, McNicholas, & Kraemer, 2004; Rodgers et al., 2013; Steinsbekk et al., 2018). In the context of EE, interoceptive processing may become a critical mechanism because, if the infants' own cues are often overridden by caregivers' behaviours, infants may become more prone to associate different internal states like emotions (e.g., anger or frustration) with eating. Developmental studies linking eating behaviours with emotion regulation and interoceptive processing are needed to directly test this hypothesis. In particular, longitudinal studies could examine how newly emerging learned behaviours and reward circuits can override visceral systems (Zeltser, 2018). Additionally, emerging evidence indicates coupling between the gastric rhythm (the rhythmic pattern of electrical activity produced by the stomach) and resting-state brain dynamics containing a wide network of regions such as somatosensory cortex, cingulate motor regions, and extrastriate body area (Rebollo, Devauchelle, Béranger, & Tallon-Baudry, 2018), suggesting a functional role for gastric inputs in perception and behaviour (Azzalini, Rebollo, & Tallon-Baudry, 2019). Future research could examine, for example, whether an increased probability for EE is associated with reduced stomach-brain coupling.

Emotion regulation

After noticing a shift in emotions, individuals may attempt to sustain (positive emotions) or change (negative emotions) the trajectory of their emotional state (Gullone, Hughes, King, & Tonge, 2010). This generally happens through emotion regulation processes (for a definition see Table 1), which could include over- or under-eating. Affect regulation models propose that eating in response to emotions helps to up- or down-regulate an emotional state (Haedt-Matt & Keel, 2011), although this is not usually an adaptive regulation strategy. Therefore, using food to regulate negative emotions may imply that humans are either poor at regulating their emotions in other ways, or that they do not possess adequate strategies for regulating emotions (Evers et al., 2010; Moyal, Henik, & Anholt, 2014). With infants and children, this could be turning away from a stimulus, the use of toys or seeking caregivers' attention for support or comfort – depending on the child's age. Primitive and reflexive forms of emotion regulation strategies (e.g. sucking, visual reorienting) develop around 3 months of age (Cole, Lougheed, & Ram, 2018; Kopp, 1982). These are gradually replaced by more elaborate, active and adaptive strategies and skills between 12 and 24 months (e.g. self-distraction) (Bridges & Grolnick, 1995; Calkins, 2007). However, such skills may develop at different rates for different children. A latent class analysis (Noroña-Zhou & Tung, 2021) found three trajectories of emotion regulation development in toddlers: steady incline (emotion regulation improved steadily), catch-up (started lowest but improved rapidly) and decline (started close to the mean but showed negative growth in emotion regulation over time). It could be proposed that those children with poor or slower developing emotion regulation abilities may be more prone to EE behaviours. Though, to our knowledge no studies have examined this hypothesis. One way to experimentally test whether individual differences in the development of emotion regulation are associated with EE behaviours may be to look at brain activity. In the infant literature, electroencephalography (EEG) has been used to measure brain activity in response to stimuli or event eliciting negative emotions, such as maternal separation (Hane, Fox, Henderson, & Marshall, 2008). For example, frontal alpha asymmetry has been adopted as an index of emotion regulation in early infancy (Hane et al., 2008; Reznik & Allen, 2018). While right frontal asymmetry is thought to indicate withdrawal and behavioural inhibition and is linked to negative affective states, left frontal EEG activity reflects motivation to approach and is linked to affective states such as happiness and anger (Depue & Iacono, 1989; Harmon-Jones, 2003). It may be that interindividual differences in frontal alpha asymmetry resulting from an interaction between the child's emotion regulation abilities and the emotional demands of the situation may index a predisposition to EE behaviours. An example of how this interrelationship may manifest comes from adult research evidencing the role of environmental stressors in explaining changes in eating behaviour (Hill et al., 2022; O'Connor & Conner, 2011; Wardle, Steptoe, Oliver, & Lipsey, 2000). Early exposure to environmental stressors affects the development of the brain, particularly prefrontal cortex–corticolimbic connectivity, and stress–response systems, such as the HPA-axis, which in turn impair emotion regulation (Blair, 2010). From a developmental perspective, we can hypothesise that environmental stressors may be conducive to difficulties in regulatory abilities and consequently predispose certain children to a higher probability for EE behaviours. Future research should directly test this compelling hypothesis.

As already discussed in *'Factors affecting children's probability for EE'*, child temperament is a critical factor implicated in the development of a probability for EE. Behaviourally, temperament has been associated with emotion regulation abilities, although it has historically been difficult to disentangle the relations between emotions and temperament from the literature (Aktar & Pérez-Edgar, 2020). Temperamental traits including negative emotionality, reactivity and intensity of emotional expression are associated with poorer infant self-regulation and the use of fewer regulation strategies (Kim & Kochanska, 2012; Thomas, Letourneau, Campbell, Tomfohr-Madsen, & Giesbrecht, 2017), which could contribute to the development of EE as a strategy to regulate emotions. Caregivers may even be aware of these effects, as their perception of toddler's emotion regulation ability was found to be negatively associated with behavioural reactivity of the child (Susa et al., 2014). This could in turn affect parenting practices with, for example, positive parenting moderating the relationship between temperament and self-regulation in toddlers (Song, Miller, Leung, Lumeng, & Rosenblum, 2018). Similarly, in a longitudinal study Kim and Kochanska (2012) showed that mutually responsive parent–child relationships at 15 months were associated with better infant self-regulation, but only for infants with high negative emotionality. Ultimately, the evidence supports the view that individual differences in temperament may often be associated to differences in emotion regulation strategies. Therefore, infants with difficult temperaments could display poorer emotion regulation skills, which may result in the use of maladaptive emotion regulation behaviours, including EE. However, the extent to which EE is displayed could be dependent on parenting styles and practices in response to their child's perceived temperament and emotion regulation abilities. Together, these factors may be linked with a higher probability for EE (Barnhart, Braden, & Price, 2021).

Appetite self-regulation

The role of appetite self-regulation (as defined in Table 1) in EE is not currently well understood and may require multiple explanations. Those who eat in response to emotions may be poorer than others at regulating their energy intake. Alternatively, abilities to regulate intake adequately may be easily affected by emotions. As physiological hunger or satiety are not the main drivers of (non) eating in response to emotions, it suggests that processes implicated in EE may override interoceptive cues of hunger, satiation and satiety (i.e. emotions might be more salient than ensuring an appropriate energy balance at any given time). Interestingly, whereas general self-regulation abilities tend to improve in children with age, there are wide individual differences in appetite self-regulation and this ability generally declines as the child gets older (A. Russell & Russell, 2021). This is important because it might indicate a critical period of increased vulnerability during toddlerhood, whereby contextual factors such as feeding practices or the feeding/eating setting are more likely to influence a child's ability to self-regulate appetite. This may cause some toddlers to change their eating behaviour in response to external food cues, or interoceptive cues other than physiological hunger and/or satiety (e.g. emotions).

Recent reviews propose appetite self-regulation to be a dual process of bottom-up signals that communicate information about hunger and satiety (as well as encompassing appetitive traits of the child), and top-down processes whereby children respond to these signals to control energy intake (Russell & Russell, 2021; Russell & Russell, 2020). It is likely that the contribution of appetite self-regulation to the development of EE in infancy may be smaller, compared with childhood, due to the underdevelopment of top-down processing at this age. However, during childhood there are many pathways through which appetite self-regulation may affect eating. These not only include EE, but also energy compensation (adjusting energy intake after consuming a preload), eating in the absence of hunger (EAH), food responsiveness and hedonics, satiation and satiety, and elements of eating microstructure (e.g. eating rate, bite size, etc.) (Papaioannou, Micheli, Power, Fisher, & Hughes, 2022; Russell & Russell, 2021). As these behavioural pathways somewhat overlap conceptually, there is potential for abilities in one pathway to link to abilities in others. For example, those children poor at calorie compensation may also EAH, as do those who EE. To some extent, these behaviours could be linked through a common external eating (see Table 1 for definition) pathway, or within a profile of food approach behaviours and traits. The trait of food responsiveness is associated with external eating, which shares behavioural characteristics with EE (Kan et al., 2020). Similarly, children with avid eating profiles appear to be characterised by high food responsiveness, enjoyment of food, and emotional overeating (Pickard et al., 2023). Therefore, it is possible that enjoying food and showing approach behaviours to external food cues could increase a child's susceptibility to poorer self-regulation of energy intake in the context of experiencing negative affect.

Appetite self-regulation is a latent variable made up of the pathways mentioned above, plus top-down processes such as food specific delay of gratification (impulsivity) and inhibitory control (Russell & Russell, 2020). As such, its role in the development of EE behaviours cannot be examined directly. Therefore, looking to other behavioural pathways may provide further insight. For example, children's (5–12 years) ability to compensate for caloric intake has been linked with tendencies to EAH (Kral et al., 2012). Three-to-seven-year-olds were shown to both undercompensate calories after a preload and EAH after a meal, although these behaviours were not correlated (Remy, Issanchou, Chabanet, Boggio, & Nicklaus, 2015). It is possible that as both behaviours occur (EAH and under compensation), poor appetite self-regulation abilities may underlie different behaviours in different situations. In studies of EE, most children EAH to some extent without experiencing any negative emotions, yet they may eat more when an emotion is elicited (Blissett et al., 2010). This could suggest that whilst suboptimal appetite self-regulation leads to some EAH, the intensity and valence of emotions experienced could disrupt this ability further (see *'The emotional stimulus'*). Therefore, it could be examined whether specific emotions interfere with appetite self-regulation, or if having poor appetite self-regulation generally lends itself to eating more in adverse circumstances.

Child and parental factors are further implicated in appetite self-regulation abilities, which may in turn predict EE. Positive feeding practices, authoritative feeding styles and implementing structured mealtimes are some factors that help the child to learn about food, meals, and eating in a positive way, which may reflect better abilities in a child's appetite self-regulation (Derks et al., 2019; Rodgers et al., 2013). Conversely, parents of avid eaters have been shown to use food for emotion regulation and be more likely to restrict food for health and weight reasons, compared with children with less avid eating profiles (Pickard et al., 2023). Utilising these practices with avid eaters could be detrimental for eliciting EE in children that already show food approach traits, enhancing their motivation to (over)consume foods. This could potentially reflect poorer appetite self-regulation abilities. For avid eaters, food may consequently have a greater capacity to regulate emotions than it does for children without these traits. To date, this area of research has not been driven by a common theoretical model, the direction and pathways between appetite self-regulation, parenting and child factors are often ambiguous. Sometimes findings point to poor appetite self-regulation moderating effects of feeding practices on children's EE (Tan & Holub, 2015), whereas other studies suggest that appetite self-regulation mediates the relationship between feeding practices and child EE (Powell, Frankel, & Hernandez, 2017). This could be the result of failing to distinguish these relationships as traits (which may mediate effects between parent/child factor and EE) with the same relationships as a state (which is more likely to moderate how much is eaten in a particular situation; see 'Context dependent nature of EE'). For example, as a mediator, parental emotional feeding practices over time may weaken a child's ability to self-regulate appetite, leading to higher EE. As a moderator, parent emotional feeding practices may have a larger effect on their child's EE at an eating occasion if the child is already poor at regulating their appetite. Nonetheless, it is clear that parent feeding practices and factors such as mealtime structure (setting food-related rules and limits, but not restriction) are associated with appetite self-regulation abilities (including EE), yet further longitudinal data (within a common theoretical framework) are required to illustrate the development of these relationships over time (Grammer, Balantekin, Barch, Markson, & Wilfley, 2022).

Summary of a probability for emotional eating

The range of child and environmental factors discussed, as well as potential mechanisms that facilitate their effects, have been shown to be associated with EE, or factors that may affect the occurrence of EE. The model we propose (Fig. 1 parts A & B) provides an individualised approach to EE, whereby each of these parts likely interact to affect a child's probability (likelihood) to eat in response to emotions when the situation occurs. This probability will be different for each child, depending on the types and extent of risk and protective factors experienced, as well as their abilities relating to the mechanisms discussed (e.g. is the child showing adaptive emotion regulation?) and the age of the child. At different developmental stages, the relative effects of each factor will vary, meaning that factors may play different roles in the development of EE, or differ in importance over time (see Fig. 1 part A). Thus far, each aspect that has been related to EE has been discussed as a trait, meaning that these are enduring factors that may predict an individual's behaviour over time. Yet, in the circumstances of EE at any given occasion, the complexity of the situation may make behaviours less predictable, with changing emotional and behavioural states, as well as environmental factors that may prompt the (non)occurrence of EE.

Context dependent nature of emotional eating

Whilst a probability for EE is important to predict its occurrence, the behaviour of EE itself is context dependent. A specific situation must present itself to the child and many contextual factors potentially affect whether EE occurs, the type of EE (over or under-eating) and amount eaten. These contextual factors relate to the emotion experienced, the available food and the environmental setting, examples of which are provided in Fig. 2. Additionally, Fig. 1 (parts B & C) illustrates that the mechanisms that facilitate EE (interoceptive processing, emotion regulation, appetite self-regulation) may have state-like effects on eating. This means that these mechanisms are not only traits (e.g. generally the child may be good at noticing internal cues), but their abilities can change during situations (e.g. there might be situational factors that make it more difficult for a child to sense or interpret a change in internal state), which may determine how EE occurs. To date, no studies have examined the contextual factors relevant to EE in children. Therefore, the following sections put forward ideas about how these contextual factors may operate in conjunction with the mechanisms outlined earlier to influence EE. For a general overview of contextual factors that could affect EE in adults, see Altheimer and Urry (2019).

The emotional stimulus

Firstly, a necessary condition for EE to manifest is the presence of an emotional stimulus, something that changes the affective state of the child. The emotional stimulus may elicit a range of emotions or moods, to each of which the eating response may differ. For example, eating in response to boredom may result in eating a different amount of food compared with eating in response to sadness (Stone et al., 2022), stress, anger, or other emotional states. Further child studies are required to investigate the nuances between specific emotional states and their effects on EE, as well as how experiences with emotional states may affect EE differently across developmental periods (e.g. there may be a developmental stage where boredom becomes an emotion that has the potential to elicit EE).

The valence of the emotion experienced is then important in determining the occurrence of EE (Macht, 2008), meaning that some children may (or may not) EE when experiencing either positive or negative affect (Moss, Conner, & O'Connor, 2021). Next, the perceived intensity and duration of emotion experienced can shape how much is eaten (Barnhart, Braden, & Jordan, 2020). Generally, mild emotions are thought to be conducive to eating, whilst intense emotions may suppress eating (Macht, 2008). Similarly, longer durations spent reacting to or experiencing emotional states could result in prolonged eating occasions and larger intakes, especially if other regulatory strategies have failed to up- or down-regulate the emotions. Here, individual differences may be apparent in the conscious awareness of a change in physiological state such as the one we experience with emotions (i.e. what counts as perturbation for me, might not count as perturbation for you). It may also be possible that the strength of the perturbation itself might differ across individuals or even within the same individual across environmental contexts. Finally, there could be individual differences in the timing of the perturbation reaching perceptual awareness. Indeed, individual differences in the intensity and duration of emotional reactivity have been observed in infancy (Bornstein & Lamb, 1992; Rothbart & Derryberry, 1981). Thus, it may be possible that infants showing a short (vs long) crying latency to a mild stressor may eat more than is required in the occasion. In each context, the subjective emotional state may override a child's ability to self-regulate appetite or appraise non-emotional interoceptive cues in order to relieve distress from negative emotions (the priority hypothesis: Tice, Baumeister, & Zhang, 2004). It is not known exactly how emotions interfere with aspects of self-regulation or the mechanisms discussed in previous sections, although many explanations have been advanced: emotions may impair executive functioning (Ursache, Blair, Stifter, & Voegtline, 2013), bias memory or shape decision making (DeSteno, Gross, & Kubzansky, 2013), or shift priorities to seek immediate gratification and ignore relevant information, resulting in disruption to long-term self-regulatory goals in order to upregulate affect (Baumeister, Zell, & Tice, 2007). Each of these explanations suggest that top-down processes are affected by the introduction of an emotional stimulus, which may reflect context dependent responses to eating cues seen in EE behaviours.

Food availability

Food must be available for the child to eat (or not eat) in response to their emotions. Depending on the child's age, this may be parental provision of food, or children having access to food in the home environment. Infancy may be a crucial period when

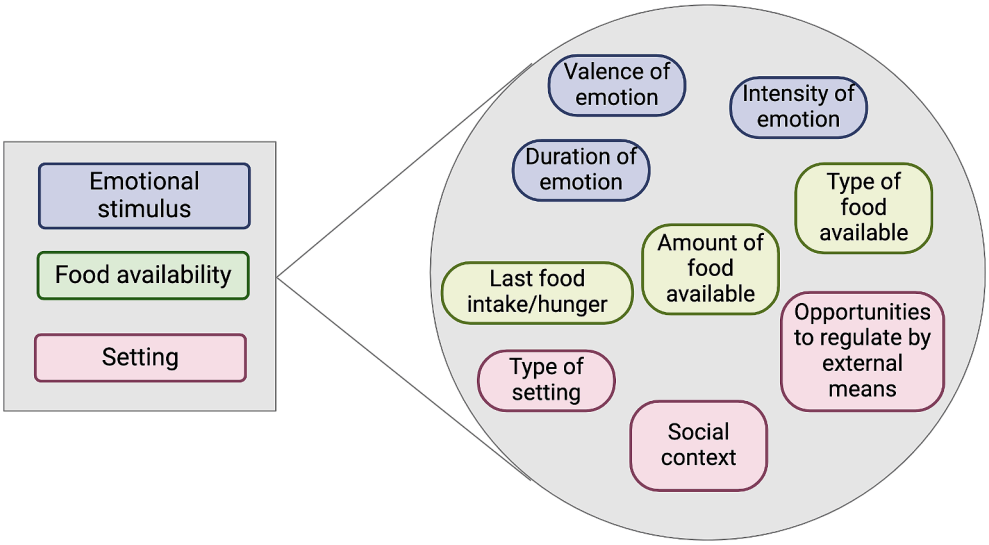

Fig. 2. Examples of context dependent factors (emotional stimulus, food availability, setting) and sub-factors that could influence the type and extent of EE in a specific occasion. The figure was created using Biorender.com.

associations between food availability and emotions are first established, with parents using feeding practices to soothe their child in response to fussing or infantile colic (Adams et al., 2019; Howard, Lanphear, Lanphear, Eberly, & Lawrence, 2006; Stifter & Moding, 2015), although this may not fully explain how emotional undereating originates. In Fig. 2 we suggest three aspects of food availability that may affect EE: type and amount of food available and perceived hunger by the child. EE tends to occur with HED foods (González et al., 2022), which infers that EE does not happen (or happens to a lesser extent) if LED foods are present. HED foods are often more palatable and rewarding than LED foods, which may help to upregulate emotions (Adam & Epel, 2007). In contrast, LED foods may be unlikely to override feelings of fullness and disrupt appetite regulation by upregulating hunger signals and activating reward systems (Erlanson-Albertsson, 2005).[3] Next, the amount of food available is likely to determine the amount eaten. Older children reporting loss of control eating have been shown to be more susceptible to the portion size effect, with differences in food cue processing highlighted in the cerebellum (English et al., 2019). Portion sizes may be especially relevant if appetitive self-regulation abilities are not yet fully developed in toddlers, meaning that their response to larger amounts of food may override internal fullness signals. Lastly, perceived hunger may moderate how much is eaten when experiencing negative emotions. In this case, EE would not only help to regulate emotions, but also to regulate appetite/energy simultaneously. However, the point that eating is driven by emotions or hunger may determine whether the eating behaviour is EE or just eating. Many paradigms overcome this by investigating EE in the absence of hunger (Blissett et al., 2010; Coulthard, Van den Tol, Jeffers, & Ryan, 2023), yet stopping EE at an eating occasion may require a trade-off between regulating emotions, appraising interoceptive cues of satiation and regulating energy intake. Other reasons for stopping eating, such as a decrease in food appeal or decreased priority of eating (Chawner, Yu, Cunningham, Rolls, & Hetherington, 2022), may become less relevant when children (or even adults) are emotionally eating.

The setting

The setting and social context likely determine whether EE will occur. This may be especially relevant for older children who have already experienced eating in a variety of settings. EE may be more likely in physical settings where EE has occurred before (e.g. at home, see *'EE as a learnt behaviour'*), although it may be dependent on whether previous associations in the same setting were congruent with the emotion currently being experienced. Similarly, the type of emotions experienced may be more likely to drive EE in different contexts. In older children, eating in response to positive emotions may occur more frequently when around others (children, family, etc.), which may be partly driven by social facilitation (Lumeng & Hillman, 2007; Zajonc, 1965). Whereas, eating in response to negative emotions may occur more frequently when the child is alone or in the presence of caregivers that are more likely to provide food in such situations. This may be linked to the opportunities available to regulate emotions by different means (e.g. toys, caregivers) and also when and where food is available. If there are fewer opportunities to regulate emotions without food, then food may be more likely to be consumed in an attempt to regulate emotions.

Adding to the complexity, each of the setting factors discussed may interact to contribute to EE in the same occasion. For example, at home, the child may be more likely to have access to food, meaning negative emotions can prompt EE. At school, food may only be

[3] Importantly, categorising emotional overeating as a problem is due to intake of excess calories and weight gain. If LED foods were consumed in response to emotions, this may pose fewer health and dietary problems to the individual.

available at break or lunch times when there are other children around. Therefore, in response to positive emotions, social facilitation may promote emotional overeating, whereas a response to negative emotions may be more likely to result in undereating due to, for example, being more self-conscious around others. Although Altheimer and Urry (2019) have previously speculated social and environmental conditions that might influence EE by adults, there is little research that has tested these hypotheses directly or with developmental populations.

Achieving end (goal) states and feedback for emotional eating

The context dependent nature of EE (Fig. 1 part B) is important for understanding its purpose as a behavioural pathway of appetite self-regulation. Appetite self-regulation can be positioned within the broader realm of self-regulation (Table 1), which is the process of reaching end (goal) states whilst monitoring progress towards this state (Inzlicht, Werner, Briskin, & Roberts, 2021). Therefore, we might infer that within the specific context, EE is a behaviour that may allow an individual to achieve their desired end state (e.g. successfully regulated affect). This starts with the child bringing to the situation a current state which is different from their desired end state. General models of self-regulation suggest that a conflict monitoring system identifies any discrepancies between these two states and implements a feedback loop that reduces discrepancy (Carver & Scheier, 1998). This is somewhat in line with predictive processing frameworks of the brain (Clark, 2013; Friston, 2010) which suggest that learning occurs by building predictions that reduce the discrepancy between expectations and incoming sensory information. One way to reduce such discrepancy is by performing actions to change sensory data (active inference, e.g. eating). Accordingly, prediction error minimization mechanisms (Barrett & Simmons, 2015) have been used to explain how incoming sensory inputs are interpreted in light of prior beliefs derived from past events and are evaluated in favour of the most likely cause of the current state of the body. From a developmental perspective, the ways infants perceive and signal their current state elicit behavioural responses from others (i.e. their caregivers), gradually leading to the development of expectations about the origin of their change in state (Atzil et al., 2018; Filippetti, 2021; Fotopoulou, Von Mohr, & Krahé, 2022). Once a caregiver has become aware of their infant's signals, they are responsible for correctly interpreting the cues and responding appropriately and promptly to them to achieve the infant's desired end state (Ainsworth, 1969).

Applying these frameworks to the development of EE, if incoming signals about the current state are noisy or unreliable, a child may rely on external cues or prior beliefs to reach the expected or desired end state. For example, a child experiencing negative affect might be more likely to accept the caregiver's food offer as a means to achieve an upregulated affective end state. As the child EE, the monitoring and predictive systems may determine whether the EE is moving, or expected to move, the current state closer to the end state. This may be reflected by more (there are large discrepancies between states; i.e. large prediction error) or less (there are small or no discrepancies between states; i.e. small or no prediction error) food being eaten (Fig. 1 part B – arrow from end state back to the extent of EE). As the current state continually changes during an episode of EE, the motivation to continue to EE also changes. This may result in slowing or stopping eating, as well as changes in behavioural expression of the current state. Alternatively, a failure to update the current state may lead to eating more than is required in the occasion. Future research is warranted to test these models in developmental populations.

These frameworks however, are not convincing to explain emotional undereating. Evidence from the disordered eating literature proposes that a sense of control over restricting intake could reduce anxiety or other negative emotions (Brockmeyer et al., 2012), as well as reduce cue reactivity to HED foods (Schnepper et al., 2021). Once children develop cognitive capacity for restraint, these explanations may be adequate for explaining emotional undereating behaviours, albeit to a lesser extreme than in disordered eating. Yet, for infants and young children, other explanations are required. One explanation could be that automatic bottom-up processes (Russell & Russell, 2020) may result in an increase in avoidance behaviours in certain situations. Alternatively, it may be hypothesised that conflicts occur between poor emotion regulation abilities and stronger appetite self-regulation abilities, which result in undereating. As the child matures, theories of self-control necessitate that a child must make decisions for longer term goal states, rather than to perform immediate behaviours that are rewarding (Stoeckel et al., 2017). Therefore, self-control (where there are conflicts between motives) or self-regulation (which can be conflict free) abilities may determine the likelihood of EE. For example, if a child has poor emotion regulation abilities, then the short-term goal state of successfully regulating affect may be met by eating (or non-eating), rather than by adaptive regulation strategies that are more beneficial for long term goals (i.e. appropriately regulated appetite and energy balance: see temporal self-regulation theory for an overview) (Hall & Fong, 2007). However, the extent to which cognitive abilities are required for these explanations is not known.

Emotional eating as a learnt behaviour

Each experience of EE is a potential learning opportunity that feeds back to the prior stages of the model and determines future eating behaviours (Fig. 1 part C – "learning feedback" arrows). Within this view, learning permeates the entire model. Even if a child has a high probability for EE (e.g. genetic inclination, temperamental dispositions, parental emotional feeding), it would not necessarily manifest into EE if they have not previously learnt to eat in response to emotions, which is often facilitated by the child's environmental and contextual factors (*see 'Context dependent nature of EE'*). Whilst EE has been previously suggested to be a learnt rather than inherited behaviour in young children (Herle et al., 2017), no model has yet suggested how EE might be learnt throughout infancy and childhood. With the proposed model, we therefore suggest two main pathways through which learning could affect the development of EE. In pathway 1, learning feeds back for future similar circumstances ($P_{context}$ – Fig. 1 part C) and in pathway 2, learning influences the factors that create an individual's probability for EE ($P_{probability}$ – Fig. 1 part C). Additionally, the relative effects of factors within the model may vary with age, meaning that learning too will be affected by age and developmental stages. For

example, as children develop they become increasingly able to select their own environments (which may be an expression of heritable traits), meaning that probability for EE may increase over time if the child selects (or learns to select) environments that facilitate eating in the context of experiencing an emotional state. In each pathway (Fig. 1 part C), different types of learning may operate simultaneously and in parallel, determining future behaviour. Importantly, the types of learning discussed below are likely to occur in much more complex ways than hereby described, with multiple stimuli and responses concurrently developing associations. The range of contextual and environmental stimuli (*see 'Factors affecting children's probability for EE'* and *'Context dependent nature of EE'*), mechanisms (*see 'Potential mechanisms of EE'*) and possible responses to and consequences of EE (e.g. emotional over or under-eating, imbalanced appetite self-regulation, dysregulated emotions, etc., *see 'Achieving end (goal) states and feedback for EE'*) all require further examination for their roles in learning to EE.

For $P_{context}$, **Classical Conditioning** frameworks would suggest (in the most basic form) that food intake (US) may be paired with a desire to eat (UR). In particular circumstances, emotions may be paired with food intake, developing into a CS. Therefore, future experiences of similar emotional states (see *'Context dependent nature of EE'*) may elicit a desire to eat (CR). Over time, conditioned incentive concepts predict that S-S* associations could develop, insofar that eating becomes an expected response to a conditioned stimulus (e.g. subjective emotional state) (Bongers & Jansen, 2017). S-S* associations have previously been shown to be important in guiding goal-directed behaviours (Berridge, 2000), such as reaching a desired end state (see *'Achieving end (goal) states and feedback for EE'*). **Operant Conditioning** frameworks can then help to explain how the consequence of EE (e.g. changes to the current state in line with the desired end state) may either reinforce or deter the behaviour (Macht & Simons, 2011). If eating to regulate emotions is successful, the extent of its success and how quickly the end state was achieved may strengthen the association between emotion and a desire to eat, resulting in EE being more likely to occur in future similar circumstances. Reinforcement concepts indicate that S-R habits may develop between affect and eating via hedonic satisfier mechanisms (e.g. palatable foods and reward pathways) or drive reduction (e.g. avoiding discomfort of negative affect) (Berridge, 2000). However, if a change in emotional valence could be attributable to other stimuli, or the end state was not achieved, these associations may not be made.[4]

There is also some evidence that **social learning** is important for children to learn to EE by observing others, such as parents. Many studies have highlighted effects of higher parental EE or emotional feeding on children being more likely to EE themselves (Braden et al., 2014; Rodgers et al., 2014; Stone et al., 2022). On one hand, this may be due to parents being more likely to use similar feeding strategies as the ones they use themselves for eating when confronted with negative emotions (Stone et al., 2022). On the other hand, observing and imitating behaviour of parents may be one way that EE develops in young children. This may extend to observing how consequences of EE affect others, such as changing their affective state. The child observer may subsequently employ EE when they themselves experience similar circumstances. Further research is required to illustrate how social learning may influence the development of EE in children and between social contexts.

In circumstances conducive to EE, the learning mechanisms discussed in $P_{context}$ are likely to be subject to **context dependent learning**. Previous research has shown that contexts can be conditioned to indicate meal settings and eating (Birch, McPhee, Sullivan, & Johnson, 1989; van den Akker, Jansen, Frentz, & Havermans, 2013). Whether, and the extent to which, EE occurs may also be dependent on the influence of the wider eating context and setting. Gershman (2017) proposes three causal structures of the relationships between cue (stimulus), context and outcome. First, the context may be independent of the cue-outcome contingency (it plays no role); second, the context may act like another cue (provides additive effects); or thirdly, context could modulate the cue-outcome contingency (i.e. there is a separate set of cue-outcome contingencies for each context). With EE, the context may be informative of the cues to EE (it has information value), which supports the idea of context as a modulatory factor. EE will therefore be likely to occur in the same settings, in response to the same emotions and context experienced previously when EE occurred. This may help to explain why self-reported emotional eaters do not always display EE behaviours in laboratory settings (Altheimer, Giles, Remedios, Kanarek, & Urry, 2021; Devonport, Nicholls, & Fullerton, 2019). Accordingly, experiences with different emotions, in different settings, may not lead to EE without associations being made in these specific circumstances. Learning theory would predict that for generalisation to occur to other circumstances, stimuli (emotions, food, setting, etc.) are required to have very similar characteristics to previous instances where EE has occurred. Again, future research can determine how specific EE behaviours are to certain circumstances, as well as the extent to which learning generalises to other emotions, settings and contexts.

For $P_{probability}$, learning feeds back to the factors that affect a child's probability for EE. Whilst learning may not affect genetic tendencies (only how they might be expressed), experiences may shape child characteristics (e.g. temperament, appetitive traits), environmental factors and individual differences in appetite self-regulation, emotion regulation and interoceptive processing (see *'Factors affecting children's probability for EE'* and *'Potential mechanisms of EE'*) over time. For example, if the child is already poor at regulating emotions with adaptive strategies, maladaptive strategies may be used more frequently (e.g. EE). Over time, reiterations of these experiences may further weaken a child's ability to adaptively regulate their emotions and affect their ability to discern among interoceptive cues that pertain to emotional states and satiation. This learning may therefore alter factors and behaviour over time, rather than changing behaviour depending on the context. Importantly, learning in $P_{probability}$ is not restricted to the individual child, but there is also potential for the environmental context to be affected. For example, caregivers may alter their feeding practices in response to their child's cues and behaviours (Agras et al., 2004; Steinsbekk et al., 2018), especially if feeding to regulate emotions is successful. Likewise, eating structures and routines may be altered to attend to the child's emotions (e.g. increasing instances of snacking). Therefore, learning over time may change a child's probability for EE through changes to mechanisms and the

[4] Alternatively, the child that regulates their emotions without eating may strengthen associations between their adaptive emotion regulation techniques and the end state, meaning that EE would be less likely to occur in the future.

environment/interactions with caregivers. However, long term changes in behaviour due to learning are often difficult to detect or disentangle from experience and maturation effects, therefore longitudinal studies would be helpful to build on these hypotheses.

Conclusions

The proposed model addresses how EE behaviours may develop throughout infancy and childhood. Alongside highlighting gaps in the literature, it offers a framework from which future research can be based to test ideas about the development of EE at different ages. Within this framework, child and environmental factors combine with mechanisms (e.g. interoceptive processing, emotion regulation and appetite self-regulation) to create a probability for EE. This approach makes it possible for EE to be individual to each person, rather than a generic response to experiencing emotional stimuli. Different combinations of environmental factors, genetics and temperament may result in different EE behaviours, as can different abilities in interoceptive processing, emotion regulation and appetite self-regulation. Importantly, our model views EE as context dependent. Although a probability determines the likelihood of EE, each eating occasion is separate, meaning that the child may not EE in every circumstance that elicits an emotion. The context is therefore key in determining whether EE will occur and its extent. We lastly emphasise the importance of learning in determining future EE. Whether the end state is reached, the associations between eating, emotions and its consequences all feed-back to similar circumstances in the future ($P_{context}$) and changes in the child's probability for EE over time ($P_{probability}$). This latter point means that children may become better or poorer at noticing and responding to interoceptive cues and regulating emotions and appetite as a result of these learning experiences. Consequently, the likelihood of EE at any given circumstance may change as a result of experience. Furthermore, EE behaviours in later childhood, adolescence and adulthood may be shaped somewhat by these early experiences. With these prepositions, the proposed model has implications for future research into EE, taking into consideration the differences between trait and state EE, mechanisms of change that may influence EE across ages, the (developmental) inter-relationships between factors, as well as accounting for contextual variables that may affect EE.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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