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Research report

Apples or candy? Internal and external influences on children's food choices

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ABSTRACT

The goal of this concise narrative review is to examine the current literature regarding endogenous and exogenous influences on youth food choices. Specifically, we discuss internal factors such as interoception (self-awareness) of pain and hunger, and neural mechanisms (neurofunctional aspects) of food motivation. We also explore external factors such as early life feeding experiences (including parenting), social influences (peers), and food marketing (advertising). We conclude with a discussion of the overlap of these realms and future directions for the field of pediatric food decision science.

Introduction

Pizza, biscuits, and chips are beloved foods. Children enjoy these tasty treats, but beyond tasting good, why do children prefer certain foods over others? Extensive research has demonstrated a host of influences on children's food choices, including genetic, familial, hormonal, environmental, and physiological determinants (Scaglioni, Arrizza, Vecchi, & Tedeschi, 2011; Weltens, Zhao, & VanOudenhove, 2014). Adults make countless food decisions during the course of a day, but even young children exert very meaningful influence over the foods they choose to consume.

The increasing current prevalence of overweight and obese youth has caused widespread concern. This is not surprising, given the grim physical, psychological, economic, and social consequences of childhood obesity (Must & Strauss, 1999; Ogden, Carroll, Kit, & Flegal, 2012). Carrying excess weight has also been linked to poorer cognitive function in both animal (Davidson et al., 2013; Davidson, Sample, & Swithers, 2013) and human research (Bongers et al., 2014; Houben, Nederkoorn, & Jansen, 2014). Because a neurocognitive decision-making process underlies all of our food choices, and because food choices are crucial to healthy behavior, further study of the *process* by which youth make food decisions is warranted.

How people make food decisions can be loosely grouped into two categories: endogenous (internal) and exogenous (external) influences. In this paper, we summarize the existing literature examining how these internal and external influences affect children's food choices. We do not provide a comprehensive review of the literature, but rather, a brief survey of behavioral and neuroimaging studies examining these endogenous and exogenous influences specifically. Endogenous states discussed will include affective states, interoception of appetitive states, and neural mechanisms of food motivation. Exogenous factors discussed will include early life feeding experiences, social settings and peer pressures, and food advertising. Because these internal and external influences overlap inextricably, the paper will conclude with a discussion of the interaction of these factors and future directions for the field of pediatric food decision neuroscience.

Internal influences

Interoception can be defined as a person's explicit awareness of internal physiological states, including heart rate, physical pain, and hunger. Scientists have studied interoception for decades, yet recent advances in technology have enabled more precise and

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quantifiable methods that have significantly deepened our understanding of interoceptive processes. Awareness of one's internal state varies according to individual differences, and though we intuitively believe that we *first* experience the world, and *then* label those experiences, a recent perspective paper challenges that notion (Barrett & Simmons, 2015). Instead, the Embodied Predictive Interoception Coding (EPIC) model purports that the *anticipation* of sensations has an important and significant impact on how we perceive the world. Below we discuss interoception and how this relates to food decisions in youth.

Interoception of pain

As with all perceptual experiences, the perception of physical pain is subjective. Pain while eating can cause feeding difficulties for children who have painful experiences early in life (Davis, Bruce, Cocjin, Mousa, & Hyman, 2010). Infants born prematurely or with complicated medical conditions may lose crucial opportunities to learn to eat and may associate eating with pain or discomfort (Zangen et al., 2003). Some of these medically complicated infants also miss the opportunity to learn typical hunger cues. For example, neonates fed by nasogastric tube or gastrostomy tube may not associate feeding with a pleasurable sensation and therefore develop oral aversions (Davis et al., 2013). Overcoming pain associated with eating can be a challenge, as can teaching children who have experienced painful events to eat orally (Burklow, McGrath, Valerius, & Rudolph, 2002), but a multidisciplinary team approach (i.e., gastroenterologist, psychologist, occupational therapist, dietician, etc.) has been shown to be effective (Davis et al., 2010).

Interoception of hunger

Interoception of hunger, also referred to as appetite, has recently become the focus of widespread scientific investigation. Many behavioral interventions emphasize improved attention to and increased focus on internal cues (hunger, satiety) to help individuals make healthier food choices (Lillis & Kendra, 2014). From a neurophysiological perspective, Simmons et al. (2013) have used functional magnetic resonance imaging (fMRI) to examine the brain's role in interoception. This research shows that the insular cortex is important for processing internal states, including heart rate, hunger, taste, and pain. The insular cortex is structurally and functionally connected to the orbitofrontal cortex, which has been shown to be critical for reward processing and evaluation (Simmons et al., 2014). Orbitofrontal cortex and lateral prefrontal cortex are also crucial for value-based decision-making and learning (Dixon & Christoff, 2014), and specifically gustatory, olfactory, and food-related evaluation (Rolls, 2015). Ventral striatum, including the nucleus accumbens, has been shown to be critical for pleasure and reward (Knutson & Gibbs, 2007), and a growing body of literature demonstrates how important ventral striatum is in stress and food cravings in youth (Gearhardt et al., 2011; Hommer et al., 2011). The interrelations between insular interoceptive awareness, orbitofrontal cortex and ventral striatal pleasure systems are particularly important for better understanding brain mechanisms that contribute to obesity.

Pleasant, delicious foods are sometimes referred to as "comfort foods" because of the emotionally appealing aspects of consumption (Weltens et al., 2014). A growing body of literature, predominantly in adult samples, has documented the role of pleasure centers in the brain, including ventral striatum, that respond to gustatory stimuli, including sucrose solution, chocolate milkshakes, colas, and fruit juices (Ng, Stice, Yokum, & Bohon, 2011; Stice, Yokum, Burger, Epstein, & Smolen, 2012). Eating in the absence of hunger is a related construct used to describe eating past the point of satiety (Reina et al., 2013). While there are likely many reasons that people eat in the absence of hunger, a strong body of research has emerged showing that brain-mediated emotional rewards may play a particularly important role in overconsumption (Vannucci et al., 2013).

Neurofunctional influences of food motivation

Functional neuroimaging has dramatically advanced the neuroscience of food motivation and eating behaviors. Research demonstrates that brain regions responsible for reward, pleasure, taste, deliberate decision-making, and self-regulation are integral for responding to food cues and for making food decisions. Specifically, the use of fMRI can help to examine the neural foundations of appetite, satiety, pleasure, and drive for food. Carnell, Gibson, Benson, Ochner, and Geliebter (2012) published a comprehensive review of neuroscientific studies of adult obesity that summarized the literature on the neurofunctional foundations of obesity. More recent studies show that, among adults, losing weight is associated with functional brain changes (Murdaugh et al., 2012) that differ according to the employed weight-loss method (Bruce et al., 2014). Whether weight loss contributes to functional brain changes among children has yet to be examined, though Verdejo-Garcia and colleagues have published foundational work demonstrating that adolescents carrying excess weight show blunted brain activations in the insula when compared to their healthy weight peers (Verdejo-Garcia et al., 2015). A quantitative meta-analysis used activation likelihood estimation (ALE) methodology and showed consistency across pediatric fMRI studies of food motivation (van Meer, van der Laan, Adan, Viergever, & Smeets, 2015). Still, there is still much work to be done examining how young children, adolescents, and emerging adults process food-related stimuli at the neural level.

External influences

Food decisions follow a developmental trajectory, beginning with feeding experiences early in life. Infants consume breast milk, formula, or, most commonly, a combination of the two. In developed countries like Canada and the United Kingdom, nearly 80% of women begin breastfeeding at birth but slightly less than 20% of women complete the six months of clinically-recommended exclusive breastfeeding (Brown, 2014). Concerns about milk supply, lack of employer lactation resources, and inconvenience are commonly cited as barriers (Brown, Dodds, Legge, Bryanton, & Semenic, 2014). This array of biopsychosocial factors, including health of the infant, social views on bottle feeding, and economic/advertising significantly influence this initial feeding decision.

Another decision facing all parents is the introduction of solid foods, recommended by World Health Organization at 6 months of age (World Health Organization, 2002). Formula feeding, as well as maternal age and health, are associated with early introduction of solid foods and subsequent deleterious health outcomes (Brown & Rowan, 2015). One food decision often influences subsequent food decisions, and future research should continue to explore the decisions of these earliest food choices.

Parental influence

Initially, the parent or caregiver makes all of the food choices for the child. Parents decide what to buy, what to store in the pantry, what to cook, when to serve, and if and when to make foods available. Studies have examined consumer food purchasing behaviors (Lusk et al., 2015), which indicate that many food attributes, including taste, perceived healthiness, and food labels, contribute to point-of-purchase decisions (von Wagner, Steptoe, Wolf, & Wardle, 2009) Parental knowledge about foods and nutrition can also shape