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Food reinforcement during infancy

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ABSTRACT

The motivation to eat, as operationalized by measuring how hard someone will work for food, is cross-sectionally and prospectively related to obesity. Persons high in food reinforcement consume more calories, and energy intake mediates the relationship between food reinforcement and obesity. Research has shown avid sucking for milk in early infancy predicts later adiposity, and the relationship between food reinforcement and excess body weight has been observed in infants as young as 9 months of age. New methodological developments in studying food reinforcement in infants and young children provide the first opportunity to study the origin of food reinforcement. This review seeks to provide background on the measurement of food reinforcement, and to present, for the first time, prenatal and postnatal predictors of infant food reinforcement. Lastly, potential mechanisms for an increasing trajectory of food reinforcement throughout development are proposed.

1. Introduction

One of the most important parts of infants' behavioral repertoire is their ability to seek and consume food; one of the first infant-mother interactions is infant feeding, either through breast or formula feeding. When a mother feeds/nurses her infant, it creates a time to foster bonding. Infants move from bottle feeding to solid food consumption at about 4–6 months (American Academy of Pediatrics, 2009), when they experience new tastes, textures, and smells that can stimulate their appetite. During this transition from a milk-based diet to a wide variety of solid foods, infants develop their food preferences. After mastering the pincer grasp, infants begin to finger-feed, which provides one of the first ways to demonstrate control over their environment. This important developmental trajectory is possible because infants come into the world prepared to eat, and they seek food, will cry when they are hungry, and gain satisfaction and pleasure from food. This is, in part, due to the fact that food is a primary reinforcer (Francis et al., 1999), and infants do not need to learn to want food. The symbiotic relationship between food as a primary reinforcer and the simultaneous infant development of sucking, chewing, gaining motor control to finger-feed themselves, and learning their autonomy in food preferences sets the stage for normal development of eating. The fact that food is a primary reinforcer (Kelley and Berridge, 2002) may provide clues to how food can become too reinforcing, leading to obesity.

Heavier infants (Kong et al., 2015), children (Temple et al., 2008b), and adults (Epstein et al., 2014a; Giesen et al., 2010; Saelens and Epstein, 1996) find food more reinforcing than leaner peers. High levels of food reinforcement also predicts greater weight gain for children (Hill et al., 2009), adolescents (Epstein et al., 2014b), and adults (Carr et al., 2014). In addition, people who find food more reinforcing consume more food in the laboratory and natural environment than those who find food less reinforcing (Epstein et al., 2011). The relative reinforcing value of food is a predictor of short and long-term weight loss, as those who lack access to alternative reinforcers to food have less treatment success (Buscemi et al., 2014).

This review will focus on reviewing evidence of the role of food reinforcement in obesity development starting as young as infancy. There are two aims of this review. First, we seek to provide a brief description of the measurement of food reinforcement, developmental perspective on food reinforcement during infancy, and mechanisms and implications for an increasing trajectory of food reinforcement that may lead to obesity. Second, we use this review to present, for the first time, prenatal and postnatal predictors of infant food reinforcement by combining three sets of data from our laboratory.

2. Measurement of food reinforcement

The basic paradigm to assess food reinforcement is similar to the paradigm for assessing the reinforcing value of drugs of abuse (Epstein et al., 2007a). The paradigm has individuals work for food on progressive ratio schedules of reinforcement. Participants earn a standardized food portion after they meet schedule requirements, and the schedule progressively increases. The maximal amount of work they perform to obtain food determines the reinforcing value of that food. The reinforcing value task is computer based and uses mouse button

Abbreviations: GWG, gestational weight gain; FRR, food reinforcement ratio.

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presses as the instrumental response. In animal laboratories it is common to assess the effect of a schedule of reinforcement on responding for food across multiple sessions, with one schedule per session. It is also common to have animals work for food on the same schedule until their responses are stable before they move on to the next schedule (Richardson and Roberts, 1996). This methodology has also been used to assess reinforcing value of drugs in humans (Bickel et al., 1991; Shahan et al., 1999). However, this paradigm is not feasible for studying individual differences in reinforcing value of food. We have adapted this technology by having subjects advance through progressive schedules within the same session, making it possible to determine reinforcing value of the food(s) studied within one session. The amount of food provided needs to be enough to warrant responding to obtain it, but not so much that subjects will become satiated and not work any longer.

The absolute reinforcing value of food is measured by having the subject only work for food, and the relative reinforcing value by providing access to food and other foods or alternatives to food on concurrent schedules of reinforcement. The relative reinforcing value has been studied in older children (Hill et al., 2009; Temple et al., 2008b) and adults (Epstein et al., 2014a; Giesen et al., 2010; Saelens and Epstein, 1996). In infants, the reinforcing value of food and alternatives to food were studied, but not in a concurrent schedules paradigm. In infant studies (Kong et al., 2016), the choices were presented sequentially in a counterbalanced fashion.

2.1. Measurement of food reinforcement in infants

There is plenty of opportunity to observe how infants use crying as an instrumental response to obtain things they want (i.e. milk), or remove unpleasant things (i.e. wet diaper, needing attention from parents) at a very early age. The reinforcing value of various stimuli has been measured in infants, including the landmark studies in which babies' level of physical activity was increased by making the motion of a mobile contingent upon movement of the baby's leg kicks (Rovee and Rovee, 1969). There have been other demonstrations that infants learn an instrumental response to get access to social, auditory/visual, and food reinforcers (Chorna et al., 2014; Lowe et al., 1983; Standley, 2003; Wormith et al., 1975). For example, research has demonstrated that 9 and 10 month-old-infants would press a large bar in front of them to obtain music or food on variable interval schedules of reinforcement (Lowe et al., 1983).

Based on this research, we adapted the reinforcing value task for older infants (≥9 months of age) by using a larger, single button response as the instrumental response in a developmentally appropriate laboratory setting (Kong et al., 2015, 2016). Nine to eighteen month old infants can make purposeful movements to reach for and grab items, most have begun to finger-feed themselves, and they can sit upright. Schedule requirements begin with one response, and progress up to 15 responses to earn a small portion of their favorite food or time accessing an alternative reinforcer. Infants work for the reinforcer until they lose interest, begin to cry, or make it clear they are finished. Our results demonstrate that the reinforcing value of food versus non-food alternatives (food reinforcement ratio, or FRR) is related to infant weight status. We have completed 3 cohorts of infants using the paradigm we developed in our lab by assessing food reinforcement versus three different alternative reinforcers: Baby MacDonald™ video (DVD; n = 27); playing with bubbles (Bubbles; n = 30); and music (Music; n = 49). The food versus non-food reinforcers were offered to the infants in a sequential fashion in each cohort. In each sample we observed a positive relationship between FRR and infant weight status across the three different types of alternatives (DVD, r = 0.60, $p < 0.001$; Bubbles, r = 0.49, $p = 0.006$; Music, r = 0.38, $p = 0.009$) (as shown in Fig. 1). The overall correlation between FRR and weight for length z-score was r = 0.49 ($p < 0.0001$).

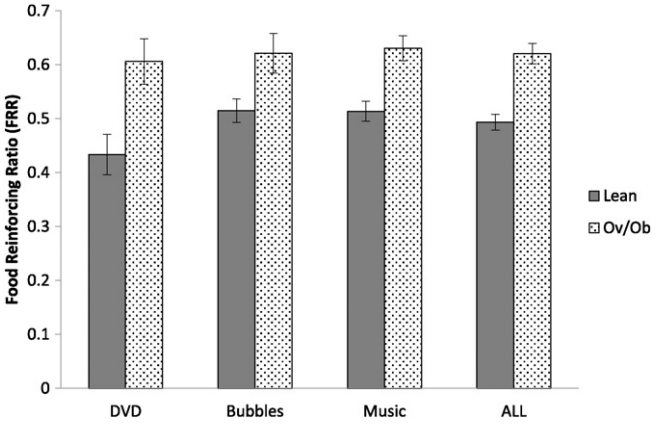

Fig. 1. Infant obesity status in relation to food/non-food reinforcement. Infants aged 9–18 months old performed the developmentally appropriate food/non-food reinforcement task in three different studies using three different types of non-food reinforcers [Study 1: watching Baby Einstein-Baby MacDonald™ (DVD), lean n = 18, overweight and obese (Ov/Ob) n = 9; Study 2: playing with bubbles (Bubbles), lean n = 17, Ov/Ob n = 13; Study 3: music engagement (Music), lean n = 37, Ov/Ob n = 12]. In the integrated sample, there were 72 lean and 34 Ov/Ob infants. Reinforcing values of food and non-food alternatives were determined using the maximum schedule achieved for food (Food P_{max}) and non-food alternative reinforcer (ALT P_{max}). Food reinforcing ratio (FRR) was determined by calculating proportion of food responses among all responses [Food P_{max} / (Food P_{max} + ALT P_{max})]. Linear regression model shows that Ov/Ob infants had significantly higher FRR-DVD (Lean: 0.43 ± 0.04 [mean ± SEM], Ov/Ob: 0.61 ± 0.05; $p = 0.009$), FRR-Bubbles (Lean: 0.51 ± 0.03, Ov/Ob: 0.62 ± 0.03; $p = 0.01$) and FRR-Music (Lean: 0.51 ± 0.02, Ov/Ob: 0.63 ± 0.03; $p = 0.002$). Similarly, when all three studies were combined the pattern of responding between lean vs. Ov/Ob infants remained consistent (Lean: 0.50 ± 0.01, Ov/Ob: 0.62 ± 0.02; $p < 0.0001$).

There is no research on measurement of food reinforcement in infants younger than 9 months of age. A developmentally appropriate instrumental response for younger infants is sucking. There have been several studies that have used sucking as an operant response to study infant learning. For example, Wormith et al. (1975) showed that infant sucking could be increased by a contingent audio cue. Investigators have shown infant sucking can be used to study infants' capability of discriminating among pure tones varying in frequency. Premature infants may have an underdeveloped sucking reflex, and making maternal voice (Chorna et al., 2014) or musical stimulation (Standley, 2003) contingent upon sucking can improve their nutritive sucking capability.

There are no studies in which food reinforcement has been assessed through sucking, though there have been several studies in which baby sucking has been measured in relationship to weight status, or growth. These studies suggest that the more intensely the infant sucks for milk or formula, the greater relative weight gain later in childhood (Agras et al., 1990; Agras et al., 1987; Stunkard et al., 2004). The intensity of sucking would suggest that those who suck more avidly for milk would meet higher response requirements to obtain milk. Food reinforcement could be studied in young infants by arranging the schedule such that the infant would need to make increasingly more sucks to obtain milk, or would have to increase the intensity of effort required to derive milk from the bottle. Either approach could be programmed on progressive schedules, so that the breakpoint could be determined. Development of a method to measure food reinforcement in young infants would be a major methodological advancement for studying how early food reinforcement develops, and studying the trajectory of how abnormal food reinforcement can develop.

2.2. Early predictors of food reinforcement in infants

By using the combined data across three studies, we assessed prenatal (maternal pre-pregnancy weight, gestational weight gain (GWG)) and postnatal (duration of breast feeding, introduction of solid foods) factors as predictors of infant food reinforcement.