Appetite 95 (2015) 310–316

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Visual illusions and inattention: Their association with adiposity among adolescent girls

Lance O. Bauer*

University of Connecticut School of Medicine, Farmington, CT 06030-2103, USA

ARTICLE INFO

Article history:
Received 8 April 2015
Received in revised form
23 July 2015
Accepted 26 July 2015
Available online 29 July 2015

Keywords:
Overweight
Obesity
Evoked potentials
Delboeuf illusion
Plate size

ABSTRACT

The Delboeuf concentric circle illusion is frequently invoked as an explanation for the hypothesized association between dinner plate size and overeating. We examined its association with adiposity among 162 girls, aged 14–18 years. We also examined the association of adiposity with neural and behavioral responses during a separate visual discrimination task. The analysis showed that girls with a body mass index percentile $\geq$ 85, or with greater triceps skinfold thickness, exhibited less sensitivity to the Delboeuf illusion than girls with normal adiposity. The excess adiposity group also exhibited significantly smaller electroencephalographic responses and more errors during the separate visual discrimination task. In combination, the findings from the two tasks suggest that girls with an elevated body mass are less sensitive to visual cues in their environment. The implications of these findings for weight loss education should be considered.

1. Introduction

The obesity prevention and treatment literature includes many simple solutions and gimmicks that have been proposed for a complex and serious health problem. An example of a simple solution is the proposal from the U.S. Department of Agriculture's Center for Nutrition Policy and Promotion (USDA ChooseMyPlate.gov) that weight-conscious consumers use smaller plates for serving food. Two mechanisms have been used to justify this proposal.

The first mechanism is the most obvious: a small plate cannot accomodate the same amount of food as a large plate. In addition, if the goal is to overeat, then a small plate challenges the consumer to exert effort and reload the plate by returning to the buffet table, kitchen, or serving bowl. Although these impediments are viewed by many health professionals as important for limiting energy intake, it is noteworthy that the research examining the association between plate size and energy intake is sparse and mostly unsupportive (Benton, 2015; Rolls, Roe, Halverson, & Meengs, 2007; Shah, Schroeder, Winn, & Adams-Huet, 2011; Yip, Wiessing, Budgett, & Poppitt, 2013).

The other mechanism justifying the proposal of a smaller plate involves a visual illusion, i.e., the DelBoeuf illusion (Nicolas, Murray, & Farahmand, 1997), which can bias a consumer's judgment of the quantity of food served on a large plate. The illusion emerges when one views two concentric circles with different diameters. When the diameter of the outer circle is increased and the ratio of the outer/inner circle diameters exceeds 4:1, a negative illusion occurs and the observer will underestimate the true size of the inner circle (Fig. 1). Various researchers (McClain et al., 2014) have extended this simple illusion involving concentric circles to dinner plates (the outer circle) of various sizes containing a meal (the inner circle) of a smaller size. They have shown that the effect generalizes to these different stimuli.

Although the DelBoeuf concentric circle illusion is reliable (Howard, Wagner, & Mills, 1973), and its connection to overeating is logical, it is not known if it contributes to the development of an overweight or obese body mass. It is also not known if it is a factor during the critical developmental period of adolescence: the illusion is greater in older than younger adults (Lorden, Atkeson, & Pollack, 1979) and might not be present during adolescence if it is sensitive to learning and life experience. One goal of the present study was to detect it in adolescent girls, aged 14–18 years, and demonstrate variability in illusion sensitivity associated with body mass.

A second goal was to examine the association between the Delboeuf illusion and another measure of visual information

* Department of Psychiatry, University of Connecticut Health Center, Farmington, CT 06030-2103, USA.
E-mail address: lbauer@uchc.edu.

http://dx.doi.org/10.1016/j.appet.2015.07.029
0195-6663/

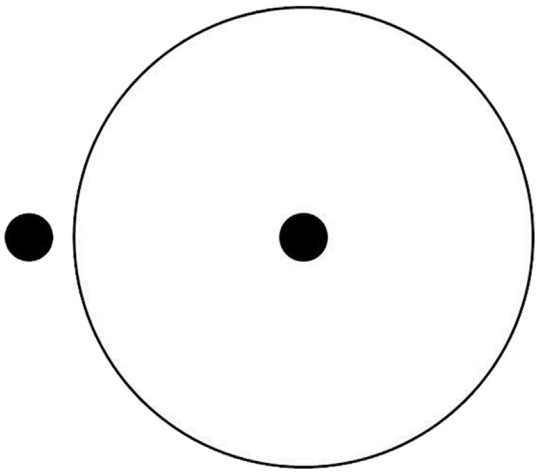

Fig. 1. Example of one trial of the DelBoeuf illusion task. The instruction to the participant was to press one response key if the black dots are the same size and a separate key if they differ in size. Across trials, the ring/dot diameter ratio of the stimulus on the right and dot size were varied. Note that the dot on the right erroneously appears smaller in diameter–this is the DelBoeuf illusion.

processing. The purpose here was to determine if sensitivity to the illusion represents a specific deficit among adolescents with an elevated body mass or is a component of a general problem. Indeed, there is already a wealth of literature demonstrating decrements in brain structure and function in this population. For example, as a group, adolescents with an elevated body mass show reduced gray matter volumes in frontal (Alosco et al., 2014; Maayan, Hoogendoorn, Sweat, & Convit, 2011) and limbic brain regions (Alosco et al., 2014). On functional tests, they differ from their normal-weight peers (Liang, Matheson, Kaye, & Boutelle, 2013; Reinert, Po'e, & Barkin, 2013) in the domains of inhibitory control, attention span, working memory, and motor skills. The findings of these studies are consistent with the robust associations shown in clinical and epidemiological studies (Anderson, Cohen, Naumova, & Must, 2006; Schwartz et al., 2014) between an elevated body mass and impulsive behavior disorders (Attention Deficit and Conduct Disorders) in which executive cognitive functions are severely affected.

The findings of the neuroimaging and cognitive studies also point to an interesting and under-appreciated contradiction: how can theorists simultaneously argue that children with an elevated body mass are more attentive than normal to the context (i.e., the illusion-inducing ring) of the Delboeuf stimulus but subnormal in their performance of most other cognitive tests? It is, of course, possible that the Delboeuf illusion is an entirely different entity. In contrast to many tasks, the Delboeuf task is simple, requires minimal attention and motor skill, and does not engage a large neural network. A better control for evaluating the specificity of the Delboeuf effect might involve a simple visual discrimination task, of the type that has been used to examine event related electroencephalographic (Bauer et al., 2010a; Bauer, 2014; Tascilar et al., 2011) potentials, such as the P300. The P300 is a positive voltage deflection in the average electroencephalographic (EEG) response to a stimulus that is novel or relevant to the task at hand. It is a neural reflection of the attentional resources engaged by the stimulus (Polich, 2007) and has often been used in studies of patients with Attention Deficit Hyperactivity Disorder and other highly impulsive or inattentive populations (Iacono, Malone, & McGue, 2003). The present study employed this simpler task and P300 EEG responses to determine the specificity of the association of the Delboeuf illusion with body mass among adolescent girls.

The final goal of the present study was to examine the association between illusion sensitivity, visual discrimination skills, and an impulsive personality. This goal is founded in previous research that has associated a personal (Anderson et al., 2006; Bauer, Yang, Houston, Kranzler, & Gelernter, 2012; Fuemmeler, Ostbye, Yang, McClernon, & Kollins, 2011; Goldstein et al., 2008; Thamotharan, Lange, Zale, Huffhines, & Fields, 2013; van Egmond-Frohlich, Widhalm, & de Zwaan, 2012; Waring & Lapane, 2008) or family history (Gearhardt & Corbin, 2009; Grucza et al., 2010) of impulsivity, or disorders characterized by high levels of impulsivity, with weight gain and obesity.

2. Methods

2.1. Participants and procedures

Adolescent volunteers were recruited with posters, direct mail solicitations, and newspaper advertisements. These advertisements mentioned weight management problems, risk-taking tendencies, conduct problems, or a family history of risk-taking or drug/alcohol abuse as potential qualifiers. Each interested volunteer and one of her biological parents were asked to call a research assistant for additional information and eligibility screening. Volunteers who reported no past or current pregnancy, psychosis, or major medical disorders that would complicate body weight (e.g., HIV, thyroid disease) or evoked electroencephalographic responses (i.e., seizure disorder, heart disease, hearing loss, uncorrected visual impairment) during the telephone and in-person interviews were deemed eligible and became participants in the protocol. They were paid for their time and effort.

Informed consent and medical release documents approved by the university's Institutional Review Board were reviewed and signed by the participant and parent on the day of data collection. On the same day, the parent completed a questionnaire reviewing the child's health history as well as a separate questionnaire that inquired about obesity, alcohol/drug dependence, and hypertension among first and second degree relatives. The parent was then dismissed and asked to return at the conclusion of the session to retrieve his/her daughter.

The participant was escorted to a private office where she completed several questionnaires assessing constructs with documented relevance to overeating or obesity. These measures of impulsivity or inattention were the Barratt Impulsiveness Scale (Stanford et al., 2009), Toronto Alexithymia Scale (Bagby, Taylor, & Ryan, 1986; Elfhag & Lundh, 2007), Borderline Symptom List (Bohus et al., 2009), and the Inventory of Callous/Unemotional Traits (Kimonis et al., 2008). Other questionnaires and interviews were administered for the purpose of describing the general background characteristics of the sample. These included a modified Drug Abuse Screening Test (McCabe, Boyd, Cranford, Morales, & Slayden, 2006), the computerized Diagnostic Interview Scale for DSMIV (Robins et al., 2002), and the 90-day Timeline Follow-back Interview for alcohol and drugs (Dennis, Funk, Godley, Godley, & Waldron, 2004).

Height and weight were measured by the research technician with a Health-o-meter™ (McCook, IL) stadiometer. The technician also measured skinfold thickness over the right and left triceps with calipers (Lange calipers, QuickMedical, Issaquah, WA) to provide a second measure of adiposity. The two technicians involved in this measurement were trained in the use of the calipers prior to study initiation. During the training period, their goal was to achieve an inter-rater reliability (intraclass correlation coefficient) greater than 0.85 within a block of 50 measurements. The maintenance of measurement reliability was checked at 3-month intervals. If needed, additional training was undertaken to return to the criterion level of reliability.