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Promising technological innovations in cognitive training to treat eating-related behavior

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ABSTRACT

One potential reason for the suboptimal outcomes of treatments targeting appetitive behavior, such as eating and alcohol consumption, is that they do not target the implicit cognitive processes that may be driving these behaviors. Two groups of related neurocognitive processes that are robustly associated with dysregulated eating and drinking are attention bias (AB; selective attention to specific stimuli) and executive function (EF; a set of cognitive control processes such as inhibitory control, working memory, set shifting, that govern goal-directed behaviors). An increasing body of work suggests that EF and AB training programs improve regulation of appetitive behaviors, especially if trainings are frequent and sustained. However, several key challenges, such as adherence to the trainings in the long term, and overall potency of the training, remain. The current manuscript describes five technological innovations that have the potential to address difficulties related to the effectiveness and feasibility of EF and AB trainings: (1) deployment of training in the home, (2) training via smartphone, (3) gamification, (4) virtual reality, and (5) personalization. The drawbacks of these innovations, as well as areas for future research, are also discussed. The above-mentioned innovations are likely to be instrumental in the future empirical work to develop and evaluate effective EF and AB trainings for appetitive behaviors.

1. Introduction

Outcomes from existing gold-standard behavioral treatments for obesity are sub-optimal, typically only producing 5–10% of body weight lost at one year post-treatment, with complete weight regain occurring for most individuals at five years post-intervention (Butryn, Webb, & Wadden, 2011). Similarly, even our best treatments for alcohol abuse are of limited efficacy (Dutra et al., 2008). One potential reason for these poor outcomes is that appetitive behavior is driven less by the explicit decision-making factors targeted by traditional treatments, and more by implicit (automatic, fast-acting, unconscious) processes and the executive functions (EF) that regulate these processes.

Two groups of such neurocognitive processes, attention bias (AB) and EF, are of special interest, given their strong connection with dysregulated eating behavior. Attention bias (i.e., preferential or selective attention to one type of information) is an unconscious cognitive process that appears to be associated with eating behavior (Castellanos et al., 2009). In particular, a large body of research suggests that increased AB towards palatable food cues predispose individuals to consume those foods (Braet & Crombez, 2003; Castellanos et al., 2009; Graham, Hoover, Ceballos, & Komogortsev, 2011; Long, Hinton, & Gillespie, 1994; Nijs, Franken, & Muris, 2010; Nijs, Muris, Euser, & Franken, 2010). For example, those with higher AB towards palatable food may be quicker to attend to unhealthy choices available in a grocery store. EF, by contrast, consists of a set of cognitive control processes (e.g., inhibitory control, working memory, set shifting) that govern higher-order, goal-directed behavior (Miyake et al., 2000). Deficits in EF are robustly associated with dysregulated eating behaviors (which, we define as including eating and drinking; Bechara & Martin, 2004; Manasse et al., 2015; Smith, Hay, Campbell, & Trollor, 2011). For example, deficits in inhibitory control (i.e., the ability to withhold an automatic response) may make adherence to calorie goals difficult, especially in the presence of palatable food/drink (Brockmeyer et al., 2016). Self-regulatory goals (e.g., to maintain a healthy diet) are also compromised by poor working

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memory (i.e., the ability to keep goal-relevant information in mind in the face of distractors; Hofmann, Schmeichel, & Baddeley, 2012).

In light of the above relationships between EF, AB, and eating, research has begun to investigate the utility of training inhibitory control, working memory, and attention bias in the hopes that doing so will improve regulation of eating-related behavior. The usual protocol for EF training involves the use of a computer to repeatedly administer tasks that become increasingly difficult as the participant improves. These protocols have proven successful in many respects, though questions remain about adherence and behavioral transfer (especially long-term) to changing eating behavior. The typical protocol for inhibitory control training is a stop-start signal task or go/no-go task in which participants are repeatedly asked to inhibit responses to stimuli when presented with a "stop" cue. The typical protocol for training working memory typically includes either or letter or number digit span task (in which participants are asked to repeat and/or manipulate a series of numbers) or a visuospatial task (in which participants are asked to remember the order of presentation of visual stimuli). The typical protocol for attention bias modification (ABM) is a visual dot probe task, in which participants are continually asked to respond to one of two stimuli; in the training version of the task, participants are repeatedly asked to respond to (and thus attend to) non-food stimuli being presented.

Several meta-analyses support the preliminary promise of EF and AB trainings for changing appetitive behaviors, but also show that effects tend to be short-term and small in size (Allom, Mullan, & Hagger, 2016; Jones et al., 2016; Turton, Bruidegom, Cardi, Hirsch, & Treasure, 2016). Two key challenges facing EF training and ABM for eating behavior are adherence to demanding training regimens and the ability to transfer gains to real-world eating decisions, especially in the longer term. Evidence suggests that EF trainings and ABM need to occur at a high frequency and/or intensity in order to have a large and lasting impact on behavior (Chein & Morrison, 2010; Kueider, Parisi, Gross, & Rebok, 2012; Richmond, Morrison, Chein, & Olson, 2011; Vinogradov, Fisher, & de Villers-Sidani, 2012). While the need for high frequency and/or intensity trainings is not a problem in and of itself, it begs the question of whether individuals are able to maintain adherence to a daily training prescription. Research in related fields suggests that individuals are often non-adherent to daily prescriptions, whether as simple as taking a pill (Tamblyn, Eguale, Huang, Winslade, & Doran, 2014) or as complicated as daily calorie self-monitoring on a smartphone (Laing et al., 2014). Although there is little evidence regarding long-term adherence to repeated EF and ABM trainings, findings thus far suggest that adherence can suffer because the training tasks are repetitive and boring.

The second main challenge facing EF trainings and ABM is their ecological validity, i.e., translation to real-world behavior. Some research suggests that EF trainings only produce limited "transfer" (i.e., only to in-lab eating behavior immediately following, or even only to response to computerized stimuli), likely because they employ "symbolic" representations of food and are largely not personalized to the individual (Guerrieri, Nederkoorn, & Jansen, 2012; Houben, 2011). Thus, innovations of EF trainings and ABM are promising to the extent that they can increase adherence to repeated training bouts and increase the external validity of training.

The aim of the current manuscript is to review five innovations being utilized or likely to be utilized in the near future in EF training and ABM of eating behaviors: (1) deployment of training in the home, (2) training via smartphone, (3) gamification, (4) virtual reality, and (5) personalization. These innovations are meant to target either or both of the challenges described above. As such, we conducted a systematized literature review in online search engines PsychINFO and PubMed using search terms for EF/attention bias (attention* bias, cognitive, executive function*, working memory, inhibit* control, set-shift*, task switch*, response inhibition, stop signal, go-no-go, impulsivity), training (training, modification, retraining, re-training, game), eating-related (food, drink, alcohol, weight, overweight, overeating, obesity, snack, eating, weight loss) and innovative methods (virtual reality, simulation, virtual world, gamif*, remote, home computer, web, internet, smartphone, application, app, phone, Android, iPhone, personaliz*, tailor*, custom*, match*, indvidualiz*). Studies were selected for inclusion in the review if they discussed one of the five innovations referenced above in the context of EF/ABM training. In discussing extant work in these areas, we comment specifically on the extent to which empirical findings demonstrate how the innovation enhanced the efficacy of the intervention on real-world eating/drinking behavior, advantages and disadvantages of the innovation and future research directions. See Table 1 for a summary of these aims for each technological innovation.

2. Deploying EF Trainings/ABM via home computer

As evidence for the necessity of repeated EF trainings/ABM continues to mount (Beard, Sawyer, & Hofmann, 2012; Chein & Morrison, 2010; Hakamata et al., 2010; Kueider et al., 2012; Richmond et al., 2011; Vinogradov et al., 2012), it is clear that finding a means to deliver remote training could enhance the feasibility and disseminability of EF and AB training programs. With the ubiquity of computer and Internet access, it is now possible to implement EF training programs remotely, e.g., on a home computer, with the same quality and reliability as in-lab training sessions. The ease of remote EF trainings makes continued repetition possible and, as such, could 1) increase effectiveness through increased dose of training and 2) maintain gains made during intervention through periodic follow-up training sessions.

2.1. Potential advantages to adherence and efficacy

Approximately 84% of U.S. households own a computer and 73% of households have connected to the Internet, which is the primary method of disseminating home computer-based EF trainings. Therefore, home-based trainings appear to be easily disseminable to the majority of the population. Importantly, home computer-based trainings have the advantage of convenience and so the presumed advantage of compliance. Users are more likely to engage in repeated computerized trainings if they are convenient and easy to use (Rainie & Cohn, 2014). Compliance levels are critical because dosage is directly related to effectiveness (Allom et al., 2016). Further, home-based trainings offer the promise of extending the efficacy of EF trainings and ABM through less frequent "booster sessions" on a weekly or monthly basis that could allow participants to maintain gains made during active training phases (Lawrence, O'Sullivan, et al., 2015).

2.2. Potential limitations

While home-based trainings present a distinct advantage of increased ease of dissemination, they also necessitate high levels of motivation in the absence of external accountability (e.g., appointments for in-lab trainings, contact with study staff, payment for study participation). For example, Houben, Dassen, and Jansen (2016) found that dietary restraint moderated the effect of their working memory training on food intake. They postulated that, because these individuals were highly motivated to be restricting their food intake, they were likely more receptive and consistent with trainings (Houben et al., 2016). Similarly, Boutelle, Monreal,

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