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The effects of lemon taste on attention, perceived exertion, and affect during a stepping task

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A R T I C L E I N F O

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Objectives: To better understand the effects of taste cues on delaying the attention shift from an external focus (dissociative) towards an internal focus (associative) as exercise intensity increases.
Design: A between subjects' experimental design with random assignment to three groups: taste (lemon-flavored mouth guards), placebo (unflavored mouth guards), or control group (no mouth guards) was used. Participants reported perceived exertion, affect (i.e., pleasantness and arousal), and attention allocation before, during, and after performing a weighted stepping task.
Results: Performing the task resulted in a gradual increase of perceived exertion, $F(1.87, 74.89) = 63.05$, $p < .05$, $\eta_p^2 = .61$, along with a shift from dissociative to associative attention, $F(2.17, 86.68) = 35.57$, $p < .05$, $\eta_p^2 = .47$ across all conditions. Additionally, participants reported feeling less pleasant and more aroused after task completion in all conditions. The lemon-flavored mouth guard failed to affect attention, $F(4.33, 86.68) = 1.41$, $p = .23$, $\eta_p^2 = .07$, perceived exertion, $F(3.74, 74.86) = .38$, $p = .81$, $\eta_p^2 = .02$, pleasantness, $F(2, 40) = .126$, $p = .88$, $\eta_p^2 = .01$, and arousal, $F(2, 40) = 2.40$, $p = .10$, $\eta_p^2 = .10$, differently than the other two conditions.
Conclusions: The study was one of the first to examine the effects of taste during an exertive task. Despite the non-significant effects of using a lemon-taste mouth guard on various cognitive variables (perception of exertion, attention allocation, pleasantness, and arousal), more scientific effort is needed to explore the effects of other tastes (e.g., sweet, bitter) and delivery methods (e.g., sprays, drops).

Sedentary behavior and physical inactivity are associated with obesity and increased health concerns such as cardiovascular disease, hypertension, and diabetes (Campbell, Khan, Cone, & Raisch, 2011). Furthermore, physical inactivity is a major national health concern with less than half (48%) of all adults in the United States of America meeting the 2008 physical activity guidelines set by the Centers for Disease Control and Prevention (CDC, 2014). Consequently, researchers have recently begun examining different strategies aimed at increasing exercise adherence (US Department of Health and Human Services, 2010).

A specific strategy that has been examined in the past decade emphasizes enjoyment during exercise by increasing attention to non-specific task cues (i.e., dissociative attention; Tenenbaum & Hutchinson, 2007). Diverting effort sensations outwards while exercising can reduce feelings of discomfort, and result in a more pleasurable experience (Connolly & Tenenbaum, 2010). Furthermore, during exertive tasks, as the workload increases, attention shifts from a dissociative mode (e.g., daydreaming, random or intentional thoughts, etc.) to an associative mode (e.g., attending to breathing, muscle soreness, etc.; Tenenbaum, 2001). The attention shift results in exercisers focusing on aversive signals (e.g., pain, increased heart rate), leading to higher levels of perceived exertion/effort, and subsequently exercise termination. Tenenbaum and Hutchinson's (2007) conceptual framework assumes a mutual relationship between perceived effort and effort tolerance. When perceived effort is reported to be low, under any task and environmental condition, the exerciser can adhere to and cope with the effort sensations longer than when perceived effort is reported to

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be high (Tenenbaum et al., 2004).

Several studies examined the effects of sensory stimulation (e.g., visual, auditory and olfactory) on attention diversion and task-related effort sensations (Basevitch et al., 2011; Horio & Kawamura, 1998; Hutchinson & Tenenbaum, 2007; Razon, Basevitch, Land, Thompson, & Tenenbaum, 2009). The rationale for conducting these studies was based on the notion that the introduction of pleasant sensory stimuli can facilitate a motivating and pleasant exercise environment. Accordingly, the pleasant exercise experience allows for longer exercise sessions because exercisers can delay the attention shift from dissociative to associative.

Evidence for this notion was found in several studies. For example, Razon et al. (2009) examined the effects of visual and auditory cues on exercise duration and attention strategies. Results indicated that visual and auditory stimuli increased task adherence and resulted in lower levels of perceived effort compared to those in occluded-vision and no-music conditions. Specifically, self-selected music resulted in lower levels of perceived exertion, and delayed the attentional shift from associative to dissociative compared to no-music conditions. Moreover, Basevitch et al. (2011) examined the effects of pleasant odors (i.e., peppermint and lavender) on perceived exertion and attention diversion. Participants smelling the lavender scent reported that the odor diverted their attention from the task at significantly higher rates than participants smelling the peppermint and placebo conditions. The authors maintained that the relaxing odors (i.e., lavender), more than the arousing odors (i.e., peppermint), have a diverting effect on attention processes. Thus, it is evident that the presentation of external stimuli (e.g. visual, auditory, and olfactory) during exercise (delays the attention allocation shift, and decreases perceived exertion (Basevitch et al., 2011; Hutchinson & Tenenbaum, 2007; Karageorghis & Jones, 2014; Razon et al., 2009). Furthermore, several studies, using the affect grid, have reported that sensory stimuli influence affective responses (e.g., Basevitch et al., 2011; Herz, 2002). For example, pleasant compared to unpleasant music, lighting conditions, and odors have been found to be related with better affective responses (e.g., Eich & Metcalfe, 1989).

Very few scientific efforts have tested the effects of taste cues on psychological (e.g., perceived exertion, attention) and behavioral (e.g., duration, performance outcome) variables during physically exertive tasks. Moreover, the effects of taste stimuli on psychological variables in other domains remain unclear. Nonetheless, with the advancement of neuroimaging technology it is evident that taste cues activate regions of the brain (e.g., anterior cingulate cortex and striatum) which control affect and behavioral reactions, as well as cognitive and attention processing (Chambers, Bridge, & Jones, 2009). In one of the few studies conducted in the exercise domain, the effect of sweet taste cues on exercise performance was studied (Mock, Mclean, & Smith, 2011). Participants in this study were provided with two different sweet solutions (i.e., carbohydrate and artificial sweetener), and a water solution during a 10-min cycling task. Findings revealed that the two sweet solutions increased participants' work rates compared to the water solution. Importantly, the authors' suggested that sweet taste cues increased exercise performance "by activating a pleasure center in the brain, altering perceived effort in the individual …" (Mock et al., 2011, p.1).

Another study compared the effects of various taste cues on heart rate (Horio, 2000). In Horio's study, participants were given oral solutions of various taste characteristics (e.g., sucrose-sweet, NaCl-salty, citrus) at different concentration levels. Findings revealed that heart rate increased gradually after the introduction of the taste cues compared to water solutions, peaking after 25 s of stimuli presentation, and enduring for up to 100 s. Additionally, heart rate increased by 7–13.6% from baseline measurements, and citric acid caused the greatest increase in heart rate (Horio, 2000). Interestingly, citric acid (sour taste) is also a preferred flavor of exercisers immediately following physical exertion (Horio & Kawamura, 1998). An additional study examined the effects of refreshing citrus-flavored water ice on brain activity and cognitive variables (Labbe, Martin, Le Coutre, & Hudry, 2011). Findings from this study indicated improvement in sustained attention in the citrus condition compared to regular water and a non-flavored water ice condition. Furthermore, Gemousakakis, Kotini, Anninos, Zissimpoulus, and Prassopoulos (2011) reported that with a sour taste there were no gender differences in frequency distribution using magnetoencephalography (MEG) whereas other taste conditions (i.e. sweet, bitter, and salty) exhibited gender differences. Thus, due to the above findings a citrus (lemon) taste was used in the present study to examine if similar effects are observed in cognitive responses such as RPE and attention.

To our knowledge, the present study was the first to examine the effects of taste cues on cognitive variables while exercising. Thus, the primary purpose of this study was to explore the effect of taste cues (i.e., lemon flavored mouth guards) on perceived exertion, attention allocation, and affect during an exertive task. Mouth guards are naturally used by many athletes during task performance and competitions (e.g., football, hockey, and basketball players), and thus, are appropriate for physically exertive tasks. Therefore, based on findings from previous studies indicating sensory stimuli influence RPE, attention, and affect, and that taste stimuli effect various brain regions and exercise-related variables, it was hypothesized that taste cues would: (1) delay the attention shift by prolonging the associative attention mode, (2) decrease perceived exertion, and (3) increase positive affect (i.e., pleasantness and arousal).

1. Methods

1.1. Participants

G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to conduct an a priori Repeated Measures Multivariate Analysis of Variance (RM MANOVA) power analysis to determine the number of participants required for the study. A large effect size (i.e., .64 – .80) was reported in several studies testing sensory stimuli effect on attention shift and RPE during exercise (Basevitch et al., 2011; Razon et al., 2009). Thus setting Cohen's $d = .7$ (Cohen, 1988), $\alpha = .05$, power $(1 - \beta) = .80$, with 3 groups (e.g., control, placebo, and taste), 8 measures (i.e., 8 time intervals), the respective sample size was set at 37.

Sixty-two participants ($N_{females} = 38$, $N_{males} = 24$) were recruited from a Southeastern university in the United States to participate in the study. However, 19 participants were removed from the data analysis due to low physical fitness according to Golding, Myers, and Sinning (1989; as cited in Morrow, Jackson, Disch, & Mood, 2011) for the Young Men's Christian Association (YMCA) step test national norms. These participants' HR after 1-min rest fell into the category of either below average, poor, or very poor for their age and gender. Thus, a total of 43 ($N_{females} = 25$, $N_{males} = 18$) participants completed the study. They were randomly assigned to the three task conditions prior to fitness testing as follows: (a) control ($N = 16$; females = 10, males = 6), (b) placebo ($N = 15$; females = 8, males = 7), and (c) taste ($N = 12$; females = 7, males = 5). Participants' average age was almost 21 years old ($M = 20.76$, $SD = 2.39$), males weighed an average of 79 kg ($M = 79.24$, $SD = 18.75$) with a mean height of 1.80 m ($M = 1.80$, $SD = .07$); females weighed an average 62 kg ($M = 61.86$, $SD = 13.17$), and a mean height of 1.68 m ($M = 1.68$, $SD = .08$). None of the participants had any