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Mind Your Diet and Move: Physical Activity Equivalent Labels Promote Healthy Behaviors and Their Cognitive Mechanisms

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Abstract

Physical activity calorie equivalent (PACE) labels provide two types of information about food: energy values and the amount of physical activity required to expend that energy, and are considered an effective strategy for addressing the increasingly serious problem of obesity. PACE labels can effectively reduce consumers' unhealthy food choices and energy intake in both laboratory and field experiments, promote healthy food choices, and simultaneously increase exercise intention and exercise behavior; that is, PACE labels can promote healthy behaviors. The cognitive mechanisms through which PACE labels exert their effects include two pathways: the PACE label-mental simulation-emotion-behavior pathway and the PACE label-mental simulation-health goal-behavior pathway. Future research can further explore the applicable groups and conditions for these two pathways, the potential negative effects of PACE labels, and integrate different dietary intervention and regulation methods to help consumers form sustainable healthy eating and exercise habits.

Full Text

Watch Your Mouth and Move Your Body: Physical Activity Calorie Equivalent Labels Promote Healthy Behaviors and Their Cognitive Mechanisms

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Abstract: Physical Activity Calorie Equivalent (PACE) labels provide two types of information about food: calorie amounts and the amount of physical activity required to burn those calories. PACE labels are considered an effective strategy for addressing the increasingly serious obesity problem. PACE labels

can effectively reduce unhealthy food choices and energy intake among consumers in both laboratory and field experiments, promote healthy food choices, and simultaneously increase exercise intention and actual exercise behavior. In summary, PACE labels can promote healthy behaviors. The cognitive mechanism of PACE labels can be integrated into a single model that includes two pathways: the PACE label-mental simulation-emotion-behavior pathway and the PACE label-mental simulation-health goal-behavior pathway. Future research can further explore the applicable groups and conditions for each pathway, the possible negative impacts of PACE labels, and integrate different dietary interventions to help consumers form sustainable healthy eating and exercise habits.

Keywords: PACE label, healthy behaviors, eating behaviors, exercise, cognitive mechanisms

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1 Introduction

Approximately 30% of the global population is overweight or obese, and the obesity trend is becoming increasingly severe worldwide (Abarca-Gómez et al., 2017; Kleinert & Horton, 2019). China' s overweight and obesity rates have also risen dramatically in recent decades. Survey data show that from 2004 to 2014, the prevalence of general obesity among Chinese adults increased from 3.3% to 14%, while abdominal obesity rates rose from 25.9% to 31.5% (Zhang et al., 2020). Another nationally representative survey from 2004 to 2018 reported similar results: the obesity rate among adults aged 18-69 in 2018 was three times that of 2004, with approximately 85 million obese individuals (48 million men and 37 million women) (Wang et al., 2021). Childhood and adolescent obesity rates in China are also rising rapidly. Surveys from 1991-2011 (Gordon-Larsen et al., 2014) and 2002-2012 (Wang et al., 2016) both revealed continuously increasing rates. Childhood and adolescent obesity rates increased from 2.1% in 2002 to 6.4% in 2012, with the combined overweight and obesity rate reaching 16%—equivalent to one in six children or adolescents being overweight or obese (Wang et al., 2016). These large-scale surveys collectively demonstrate that overweight and obesity have become increasingly serious problems among both Chinese adults and youth.

Although the origins of obesity are complex, its fundamental cause is energy intake exceeding energy expenditure (Gortmaker et al., 2011). The widespread obesity trend is also considered a product of the modern industrialized environment, which promotes excessive food intake while reducing daily physical activity (Hill & Peters, 1998). On the one hand, modern society has reduced physical activity in daily life, thereby decreasing energy expenditure. On the other hand, modern society is saturated with tempting, high-calorie, high-fat,

and high-sugar unhealthy foods that lead to overeating (Wadden et al., 2002). Research indicates that China's rapidly climbing overweight and obesity rates in recent decades are also associated with significant changes in dietary structure and lifestyle, specifically increasing consumption of animal-source foods, refined grains, and highly processed foods, alongside declining physical activity levels due to prolonged sedentary behavior (Pan et al., 2021).

In response to the growing obesity problem, the "Healthy China 2030" initiative has set the goal of "significantly slowing the growth rate of overweight and obese populations." Exercise and healthy eating are essential for maintaining a healthy weight (Kumanyika et al., 2008), and encouraging healthy eating and physical activity are two important strategies for weight control. Therefore, effectively controlling and reducing unhealthy food intake while increasing exercise behavior is of great practical significance for achieving the national health strategy.

In promoting healthy eating, traditional policies and interventions such as health education campaigns and consumption restrictions have failed to produce good results, and some more stringent measures (such as taxing high-calorie and high-sugar foods) have even produced negative effects (李佳洁，于彤彤, 2020). In this context, "non-coercive but not laissez-faire" nudging strategies have become a focus of attention for academics and policymakers. Nudging strategies can better suppress the irrational side of individuals' food choices, where cues or stimuli can help people make healthier food choices consciously or subconsciously (李佳洁, 于彤彤, 2020; Papies, 2016). In the healthy eating domain, food labels that provide decision-making information are considered an effective nudging strategy. However, the food labels currently used in China are complex, information-heavy, and require calculation, making them limited in promoting healthy eating (Campos et al., 2011). Based on this, researchers have proposed simpler, more intuitive "front-of-package" (FOP) labels that display only the most important health information. Many countries have adopted various FOP labels, such as the "Multiple Traffic Lights" (MTL) labels used in the UK, the Guideline Daily Amounts (GDA) labels used in Mexico, health warning labels used in Chile, Brazil, and Canada, Nutri-Score labels used in France, Belgium, and Spain, Guiding Stars labels used in the US and Canada, and the Health Star Rating system used in Australia and New Zealand. Numerous studies have found that FOP labels can prompt consumers to make healthier food choices (Brown et al., 2018; Cecchini & Warin, 2016; Nikolova & Inman, 2015; Temple, 2020).

Among the various types of FOP labels, Physical Activity Calorie Equivalent (PACE) labels have attracted increasing research attention over the past two decades. Unlike other FOP labels, PACE labels simultaneously provide two types of information: the food' s calorie content and the amount of physical activity required to burn those calories. The physical activity information typically consists of two parts: a simple "stick figure" exercise icon above, and below it, the time or distance required for that exercise type (e.g., jogging, walking)

to burn the food' s calories (e.g., jogging for 40 minutes). Existing research has found that regarding healthy eating behavior, PACE labels can prompt individuals to choose lower-calorie foods (Antonelli & Viera, 2015; Dowray et al., 2013; Viera & Antonelli, 2015), reduce individuals' energy intake (Daley et al., 2020), and make healthy products more attractive (Mehlhose et al., 2021). PACE labels not only reduce individuals' energy intake but also have the added benefit of encouraging exercise (Antonelli & Viera, 2015; Deery et al., 2019), prompting dieters to reduce high-calorie food intake and increase physical activity (Jin et al., 2020). In fact, weight control can be achieved through simple arithmetic combinations of increasing energy expenditure or reducing energy intake (Okada, 2019). National survey data show that reducing daily energy balance by 100 kcal (through a combination of reduced intake and increased activity) can prevent weight gain in most of the population (Hill et al., 2003), and reducing daily energy balance by 50–100 kcal has practical significance (Hill et al., 2003; Rodearmel et al., 2007). Therefore, scholars believe that PACE labels have the advantage of simultaneously promoting consumers' healthy eating behavior and exercise behavior, thereby effectively addressing the increasingly serious obesity problem.

This paper summarizes empirical research on PACE labels in promoting healthy eating and exercise behavior, organizes their mechanisms of action, and further integrates a theoretical model of how PACE labels promote healthy behavior, hoping to provide references for theoretical development and practical application.

2.1 Laboratory Studies

Laboratory studies simulating food choices have shown that PACE labels can influence consumers' attitudes toward food and promote healthy eating behavior. Compared with other labels, consumers show a preference for PACE labels, believing they can help them make better food decisions (Dowray et al., 2013; Elbel et al., 2009; Evans et al., 2016; Swartz et al., 2013; Wolfson et al., 2017). Although PACE labels did not significantly affect snack liking ratings or expected consumption of unfamiliar snacks, they significantly reduced both expected and actual consumption of familiar snacks among college students (Hartley et al., 2018). Research on Chinese participants (primarily those under 45) also showed that PACE labels increased preferences and positive attitudes toward healthy foods (dates and walnuts) while reducing preferences for unhealthy foods (potato chips) (Yang et al., 2021). Further analysis revealed that PACE labels presenting walking time had a greater effect on healthy eating behavior than those presenting jogging time or calorie-only labels. Additionally, individuals with higher future time perspective (FTP) more frequently chose healthy foods with PACE labels and less frequently chose unhealthy foods with PACE labels (Yang et al., 2021).

PACE labels can also reduce consumers' willingness and behavior to choose high-calorie beverages and foods. An online study of over 1,000 regular alcohol

consumers found that PACE information on beverages reduced their intention to consume high-calorie drinks such as beer and wine (Robinson et al., 2022). Eye-tracking studies showed that when PACE labels appeared on foods and beverages, consumers (adults aged 18–40) paid more attention to and more frequently chose healthy foods and beverages, and this effect was more pronounced among individuals with lower physical activity and health behavior levels (Mehlhose et al., 2021). Compared with calorie labels, PACE labels significantly increased the likelihood of adults aged 16–64 choosing lower-energy foods or beverages, and this effect remained even after controlling for important individual factors such as BMI, dietary restrictions, physical activity, and health literacy (Masic et al., 2017).

Online simulation studies randomly assign participants to different food label conditions to simulate consumer food choices in restaurants and calculate the energy content of selected foods. In a study with over 800 participants, 82% preferred menus with PACE labels (presenting energy as walking distance or walking time) over menus with no information or only energy information, and participants selected foods with the lowest energy content when energy was presented as walking distance (Dowray et al., 2013). Using the same four menu types, a study of 1,000 adults across 47 US states found that PACE labels presented as walking time significantly reduced the energy content of foods ordered by adults for themselves (Antonelli & Viera, 2015) and also significantly reduced the energy content of foods ordered by parents for their children (Viera & Antonelli, 2015).

In the "swap acceptance" research paradigm, researchers first ask participants to select a food item, such as a sweet snack, salty snack, beverage, or lunch. Participants are then presented with swap options that are similar to their initial choice in other aspects but contain at least 50 fewer kilocalories. Along with the swap options, researchers randomly present food information, such as vague energy information ("Lower energy, would you like to swap?"), precise energy information ("208 fewer calories, would you like to swap?"), exercise information required to burn the food' s energy (i.e., PACE label: "208 fewer calories, equivalent to 46 minutes of brisk walking, would you like to swap?"), or no information for the control group ("Would you like to swap?"). Participants' swap probability is then analyzed as the dependent variable. Results showed that compared with the no-label control group, adding PACE information to beverages, foods, or menus significantly increased participants' swap probability (Breathnach et al., 2021; Breathnach et al., 2020).

In summary, laboratory results indicate that PACE labels presented on foods or beverages are preferred by consumers and can effectively reduce unhealthy food choices and decrease the energy content of selected foods or beverages.

2.2 Field Study Results

Field studies have also shown that PACE labels can promote consumers'selection of healthier foods and beverages. A study in a university cafeteria found that PACE labels effectively reduced students' selection of sugar-sweetened beverages and increased their selection of water, fruits, and vegetables (Scourboutakos et al., 2017). Compared with no-label conditions, PACE labels significantly reduced both the energy content of foods ordered and actually consumed by college students at lunch, and PACE labels did not affect energy intake after lunch. In other words, college students in the PACE label group consumed less energy at lunch and did not compensate by eating more snacks in the afternoon (James et al., 2015). A randomized field experiment during the Christmas period showed that compared with traditional healthy living leaflets, presenting PACE information on commonly consumed holiday foods and beverages along with advice on regular self-weighing and weight management effectively prevented weight gain in adults during the Christmas period (Mason et al., 2018). Two longitudinal studies found similar results. In low-income neighborhoods in West Baltimore, researchers placed different types of labels in four convenience stores near middle schools—precise energy information, percentage of daily recommended intake, or PACE information—to examine the effects on adolescents' sugar-sweetened beverage purchases. After monitoring Black adolescents' beverage purchases for six weeks, results showed that PACE labels displayed in convenience stores significantly reduced purchases of sugar-sweetened and sports drinks while increasing water purchases (Bleich et al., 2012). In a two-year field experiment in North Carolina (with one year of baseline measurement and one year of label intervention), researchers presented PACE labels in one cafeteria and calorie labels in two other cafeterias. During both baseline and intervention periods, researchers photographed participants' ordered foods and calculated energy content during two weeks of every three-month period, and recorded accelerometer data (including sedentary, light, and moderate-to-vigorous physical activity time) during one week of every three-month period. Compared with baseline, the energy content of consumers' lunch selections decreased significantly, and this effect remained even after controlling for age, gender, race, occupation, arithmetic ability, and health literacy level (Viera et al., 2019).

Some individual studies have found inconsistent results regarding the effect of PACE labels on food ordering. A 12-week field study conducted in 10 cafeterias in the UK found that presenting PACE labels did not significantly affect participants' food choices, with only four cafeterias showing significant reductions in selected food energy, five showing no significant differences, and one even showing a significant increase (Reynolds et al., 2022, preprint). However, most studies indicate that compared with no labels, both PACE labels and calorie labels can significantly reduce the energy content of foods selected or consumed by consumers, with similar effects (Antonelli & Viera, 2015; Dowray et al., 2013; James et al., 2015; Pang & Hammond, 2013; Platkin et al., 2014; Reale & Flint, 2016; Robinson et al., 2022; Seyedhamzeh et al., 2018; Viera et al., 2019; Viera

& Antonelli, 2015). Meta-analyses have also shown that PACE labels have advantages over other types of food labels or no labels in reducing the energy content of foods selected and consumed from menus (Daley et al., 2020).

In summary, results from both laboratory and field experiments indicate that PACE labels on foods, beverages, or menus can effectively reduce the energy content of foods selected and consumed by consumers, promoting healthy eating intentions and behaviors.

3 Effects of PACE Labels on Exercise Behavior

Although research evidence on PACE labels' influence on exercise behavior is limited, overall results show that PACE labels can enhance participants' exercise intentions and promote exercise behavior. In a survey of over 800 people, 40% reported that PACE labels were more likely to influence their food choices compared to 28% for calorie labels, and 64% of participants reported that PACE labels were "somewhat likely" or "very likely" to influence their physical activity levels compared to 49% for calorie labels (Antonelli & Viera, 2015). Moreover, compared with calorie labels, adults reported that PACE labels would motivate them to encourage their children to exercise (Viera & Antonelli, 2015). A laboratory study examined the effects of PACE labels on dieters' food intake and subsequent physical activity, finding that compared with non-dieters, PACE labels significantly reduced dieters' food intake and increased their post-consumption physical activity (objectively measured on a treadmill), thereby greatly promoting energy balance (Jin et al., 2020). In a two-year field study, researchers first collected one year of baseline data, then randomly presented PACE labels on foods in one cafeteria and calorie labels in two other cafeterias for one year. Both baseline and intervention periods recorded participants' self-reported and objectively measured physical activity indicators. Results showed that compared with calorie labels, PACE labels increased both self-reported and objectively recorded physical activity indicators. Specifically, self-reported moderate-to-vigorous physical activity (MVPA) increased by 24 minutes, while objective accelerometer data showed modest increases in step count and MVPA duration and reduced sedentary time. Although the effect sizes were not large, they indicate that PACE labels can have long-term effects on consumers' physical activity (Deery et al., 2019).

4 Cognitive Mechanisms of PACE Labels

Although numerous studies have demonstrated the effectiveness of PACE labels in promoting healthy eating and exercise behavior, systematic theoretical explanations of their cognitive mechanisms are still lacking. This paper organizes existing research findings and integrates a cognitive model of how PACE labels exert their effects, including two pathways (Figure 1 [Figure 1: see original paper]).

Figure 1 presents a cognitive model of how PACE labels promote healthy be-

havior. The model includes two pathways. The first pathway is the PACE label-mental simulation-emotion-behavior pathway, where PACE labels influence individuals' emotional responses to food consumption through mental simulation, thereby affecting eating behavior. The second pathway is the PACE label-mental simulation-health goal-behavior pathway, where PACE labels activate individuals' health goals through mental simulation, subsequently influencing eating behavior and exercise-related behavior. Additionally, health goal activation may further influence individuals' emotional responses to food consumption, thereby affecting food decisions and behavior.

4.1 PACE Label-Mental Simulation-Emotion-Behavior Pathway

Some researchers speculate that the psychological mechanism by which PACE labels promote healthy eating is related to mental simulation and negative emotions (Montford et al., 2017). Researchers compared the effects of different exercise types on PACE labels (cycling vs. walking) on food choices, finding that compared with PACE labels showing low-difficulty exercise (walking), high-difficulty exercise (cycling) labels showed greater effectiveness in reducing expected consumption of unhealthy foods. Further analysis revealed that the effect of PACE labels on expected consumption of unhealthy foods was mediated by anticipated negative affective responses, but had no effect on healthy foods. Therefore, Montford and colleagues proposed that PACE labels showing high-difficulty exercise may activate stronger mental simulation of the exercise and food consumption experience, thereby increasing the perceived visualization of the costs and consequences of food intake, ultimately reducing energy consumption (Montford et al., 2017).

We refer to this cognitive mechanism as the first pathway: the PACE label-mental simulation-emotion-behavior pathway. Specifically, PACE labels spontaneously generate mental simulation of exercise, which triggers emotional responses to consuming the food, thereby changing food decisions and responses. Mental simulation refers to the process by which people simulate past experiences, feelings, and behaviors when facing a new situation, enabling them to make corresponding decisions (Barsalou, 2003, 2008). When participants see food-related cues, such as food pictures, they spontaneously simulate past experiences of consuming the food and its effects, including the food' s shape, color, taste, texture, and reward responses (Chen et al., 2016).

PACE labels consist of two components: a "stick figure" exercise image (e.g., jogging or walking) and numerical values (e.g., distance or duration). The stick figure depicts an unbalanced state through the twisting of limbs and torso, becoming an implied motion stimulus that requires high-level cognitive participation (李开云等, 2015). Early research found that implied motion stimuli activate cognitive processing such as motor imagery. For example, Urgesi et al. (2006) used brain imaging to find that when participants viewed static pictures of human hands, mirror neurons in motor and premotor cortices were similarly activated. Proverbio et al. (2009) also found that complete implied motion human

pictures more strongly activated mirror neuron regions related to movement compared with static human pictures in the control group. Therefore, when individuals see exercise-related images on PACE labels, they spontaneously activate exercise-related brain activity and mentally simulate the feelings and experiences of exercise. In other words, when PACE labels are presented on food cues, individuals mentally simulate not only the consumption of the food but also the required exercise and its experience after consumption (e.g., jogging for 30 minutes), forming a new response and decision.

The spontaneous mental simulation of exercise elicited by PACE labels produces corresponding emotional responses. Qualitative focus group studies show that adolescents from higher socioeconomic backgrounds display guilt about consuming unhealthy foods, such as "I always feel guilty when I eat fast food, so I try to choose healthier options at fast food restaurants" (Evans et al., 2016). PACE labels significantly reduce liking ratings, taste ratings, and positive emotion ratings (such as satisfaction, pleasure, and contentment) for unhealthy foods (e.g., potato chips), while increasing fat content ratings and negative emotion (i.e., guilt) ratings for chips. However, PACE labels do not affect liking ratings for healthy foods (e.g., yogurt and juice) (Oliveira et al., 2020). Compared with no labels, PACE labels reduce positive emotions toward exercise (Lee & Thompson, 2016). Compared with shorter-duration PACE labels (more energy expended per unit time, such as running, rope skipping, swimming), longer-duration PACE labels (e.g., walking) have greater effects on reducing unhealthy eating and promoting healthy food choices (Huang et al., 2022; Yang et al., 2021).

Further analysis found that anticipated guilt mediates this effect and is moderated by consumers' future self-continuity, such that individuals with high self-continuity have higher self-control ability and expectations for future outcomes, and using longer-duration PACE labels leads them to experience higher anticipated guilt, thereby reducing energy intake (Huang et al., 2022).

According to the "feeling-is-for-doing" perspective, anticipated emotions play an important motivational role in behavior (Zeelenberg et al., 2008). Generally, due to negativity bias, negative information and emotions have greater influence on decision-making processes (Rozin & Royzman, 2001). Research on healthy food choices found that anticipated negative emotions toward food mediated the reduction of high-calorie food intake and increase of low-calorie food intake (耿晓伟等, 2018). In other words, when people anticipate negative emotions from consuming high-calorie foods, they are more inclined to reduce high-calorie food intake and increase low-calorie food intake. When PACE labels are presented on unhealthy foods—for example, that consuming 100 grams of potato chips requires jogging for 42 minutes (or 6.68 kilometers)—spontaneous mental simulation generates negative emotions (e.g., guilt), thereby reducing consumption of unhealthy foods. This pathway can well explain the above findings, such as why PACE labels showing higher exercise difficulty (Montford et al., 2017) or longer-duration PACE labels (Huang et al., 2022; Yang et al., 2021) are

more effective in reducing unhealthy eating, because such PACE labels generate stronger negative emotions during mental simulation, and negative emotions mediate the effect of PACE labels on unhealthy foods (Huang et al., 2022) and have greater influence on food decision-making processes (Rozin & Royzman, 2001). However, when PACE labels are presented on healthy foods—for example, that consuming 100 grams of tomatoes requires jogging for 2.5 minutes (or 0.4 kilometers)—the impact on liking ratings for healthy foods (e.g., yogurt and juice) is smaller (Oliveira et al., 2020), and it is more difficult to elicit strong negative emotional responses, with no emotional mediation effect found (Montford et al., 2017), and may even increase consumers' positive emotions toward healthy foods (Yang et al., 2021).

In short, PACE labels on foods cause individuals to spontaneously simulate the required exercise and its experience after consumption, thereby influencing emotional responses and food decision-making. This pathway emphasizes that negative emotions generated by mental simulation of exercise reduce selection and consumption of high-calorie foods and may be more effective for individuals who dislike exercise and have lower health levels. Existing research found that PACE labels on foods and beverages promoted healthy food choices, and this effect was more pronounced among individuals with lower physical activity and health behavior levels (Mehlhose et al., 2021). Future research can further systematically explore the populations and conditions under which this pathway is effective.

4.2 PACE Label-Mental Simulation-Health Goal-Behavior Pathway

The second pathway through which PACE labels exert their effects is the PACE label-mental simulation-health goal-behavior pathway. PACE labels on foods trigger spontaneous mental simulation and exercise imagery, which activate higher-level health goals, thereby promoting healthy eating and exercise behavior. This pathway is consistent with transfer theory in the health domain, which suggests that behavior in one health-related domain may influence behavior in another health-related domain (Mata et al., 2009), meaning that individuals who value healthy eating may also value regular exercise. One study compared the effects of 5 minutes of actual exercise versus 5 minutes of imagined exercise (i.e., mental simulation) on subsequent snack intake, finding that compared with the control group, the imagined exercise group significantly reduced energy intake, while the actual exercise group did not differ from the control group. Researchers proposed that imagined exercise may activate higher-level health goals, leading to generalization of healthy behavior that transfers to eating behavior (Inauen et al., 2018), suggesting that transfer effects may underlie the effectiveness of PACE labels.

Research shows that the effectiveness of PACE labels on healthy eating depends on participants' health motivation or health awareness, meaning that labels presented on foods are more likely to activate health goals in individuals with high health motivation or awareness, providing supportive evidence for this pathway.

For example, PACE labels only reduced snack liking ratings among individuals who paid more attention to health (Hartley et al., 2019). Consumers who chose foods based on healthiness used calorie or PACE labels more frequently and selected foods with lower energy content (Shah et al., 2016). When PACE labels were presented on foods, health-conscious consumers selected foods with significantly lower energy content than less health-conscious consumers, indicating that PACE labels have greater impact on individuals with higher health awareness (Montford et al., 2017). Research on obese populations found that compared with the control group, presenting calorie labels, nutrition information labels, or PACE labels all increased participants' thoughts about weight control and reduced the energy content of their selected foods (Reale & Flint, 2016). Research on dieting populations found that PACE labels may activate dieters' energy balance goals, thereby reducing their food intake and increasing their post-consumption physical activity (Jin et al., 2020). Because individuals with higher future time perspective have higher health awareness (Kooij et al., 2018), a study on Chinese adults found that individuals with higher future time perspective reduced their selection of unhealthy foods with PACE labels and increased their selection of healthy foods (Yang et al., 2021). These studies indicate that for individuals with high health awareness or energy balance goals (e.g., dieters), mental simulation triggered by PACE labels can better activate their health or energy balance goals, thereby reducing their selection and intake of unhealthy snacks, while health goal activation may also influence subsequent exercise behavior.

The second pathway can well explain the effects of PACE labels on subsequent exercise behavior. The exercise imagery triggered by PACE labels and the resulting mental simulation activate participants' health or exercise goals, thereby increasing consumers' own exercise intentions (Antonelli & Viera, 2015), their intention to encourage children to exercise (Viera & Antonelli, 2015), and their post-consumption physical activity levels (Jin et al., 2020). Research shows that mental simulation enhances health-related goals, strengthens motivation, and helps achieve health goals (Greitemeyer & Würz, 2006; Renner et al., 2019). Mental simulation of exercise is an effective method for promoting health behavior change (Cameron & Chan, 2008; see review Conroy & Hagger, 2018) and is commonly used in sports psychology to improve exercise performance, adherence, and intention (Andersson & Moss, 2011; Cumming & Williams, 2012; Duncan et al., 2012; see review Kossert & Munroe-Chandler, 2007). For example, research shows that exercise imagery and mental simulation interventions can increase self-reported physical activity among older adults (Kim et al., 2011) and reduce students' fatigue perception while enhancing their exercise adherence (Razon, 2012). Thus, mental simulation of exercise triggered by PACE labels promotes individuals' subsequent exercise intentions and behavior.

Meanwhile, the second pathway can also well explain the effects of PACE labels on healthy foods. Different types of foods may differ in mental simulation processes, with unhealthy foods (e.g., cake) triggering more short-term impact-related simulations (e.g., hedonic), while healthy foods (e.g., fruit) trigger more

long-term impact-related simulations (e.g., health) (Piqueras-Fiszman, 2020). Meta-analysis results show that presenting low-energy healthy foods can prime participants' health goals and significantly reduce subsequent food intake (Buckland et al., 2018). Therefore, PACE labels on healthy foods bring more long-term impact-related mental simulation, priming individuals' health goals and leading to behaviors consistent with those goals—namely, reducing unhealthy food intake and increasing healthy food intake.

Notably, health goal activation may also influence individuals' emotional responses to consuming the food, thereby affecting subsequent behavior. Research found that PACE labels only reduced snack liking ratings among individuals who paid more attention to health (Hartley et al., 2019), suggesting that for more health-conscious individuals, mental simulation triggered by PACE labels can effectively activate their health goals, thereby reducing their ratings of unhealthy snacks. Geng Xiaowei et al. (2018) found through health goal priming that activating health goals reduced predicted pleasure scores for high-calorie foods and increased predicted pleasure scores for low-calorie foods, thereby reducing high-calorie food selection and intake while increasing low-calorie food selection and intake.

In short, after health goals are activated, individuals adopt behaviors consistent with health goals in both healthy eating and exercise—namely, reducing unhealthy eating and increasing physical activity. Meanwhile, the process of mental simulation and health goal activation may generate negative emotions after consuming unhealthy foods, thereby reducing unhealthy food choices. This pathway emphasizes that mental simulation of exercise activates health goals, reducing selection and consumption of high-calorie foods while increasing exercise intentions and behavior. Therefore, it may be more effective for individuals with higher health awareness and health literacy or those with energy balance goals (e.g., dieters). Future research can further systematically explore the populations for which this pathway is effective.

5 Summary and Outlook

This paper summarized research on PACE labels in promoting healthy eating and exercise behavior. Both laboratory and field experiments show that PACE labels can reduce consumers' selection and intake of unhealthy foods while increasing subsequent exercise intentions and behavior. Integrating existing evidence, this paper further developed a cognitive model of PACE label effects, including two pathways. The first pathway is PACE label-mental simulation-emotion-behavior, where PACE labels influence individuals' emotional responses to food consumption through spontaneous mental simulation, thereby affecting food decisions and behavior. The second pathway is PACE label-mental simulation-health goal-behavior, where PACE labels activate individuals' health goals through spontaneous mental simulation, thereby influencing health-related behaviors (including eating behavior and exercise behavior). The proposal of this theoretical model can provide references for theoretical development and

practical application of PACE labels.

Although previous research has conducted numerous laboratory and field studies on PACE labels' promotion of eating behavior, and a few studies have explored their promotion of exercise behavior, future research can pursue deeper investigation in several directions. First, the two cognitive pathways of PACE labels may have strong individual dependencies—the first pathway may be more effective for individuals with low physical activity levels or who dislike exercise, while the second pathway may be more effective for individuals with health goals or energy balance goals. However, existing research rarely examines this issue, and future research can further explore the applicable populations and conditions for different pathways and methods to enhance PACE effects. Second, short-term versus long-term effects of PACE labels. Most existing research examines immediate effects, with only a few field studies exploring long-term effects on food selection (Viera et al., 2019) and exercise (Deery et al., 2019). Future research can further examine the long-term impacts of PACE labels on consumers' physical and mental health, such as whether PACE labels may have adverse effects, cause individuals to overly focus on food calories while ignoring nutritional components, or reduce individuals' pleasure in eating. Third, different exercise types on PACE labels (jogging, walking) influence PACE label effects (Huang et al., 2022; Montford et al., 2017; Yang et al., 2021), and future research needs to further explore the exercise types with the greatest effects in different populations (e.g., adolescents, elderly, males, females, low health level groups, low physical activity individuals). Fourth, PACE labels increase negative emotions toward unhealthy foods, but few studies have explored potential negative effects on certain populations, such as those with eating disorders and dieting populations. Future research also needs to explore the potential negative effects on these populations and prevention and improvement measures. Finally, healthy eating behavior interventions cannot rely solely on PACE labels but need to integrate different dietary interventions and regulation methods, such as intuitive eating and mindful eating, while improving individuals' awareness and ability to identify and understand food nutrition labels, enhancing individuals' health literacy, and ultimately forming sustainable healthy eating and exercise habits.

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