British Journal of Health Psychology (2013), 18, 354–368

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Using stop signals to reduce impulsive choices for palatable unhealthy foods

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Objective. Exposure to palatable foods in the environment can trigger impulsive reactions to obtain them, which may lead to unhealthy food choices and eating behaviour. Two studies tested the fundamental question whether impulsive unhealthy food choices can be altered by means of linking unhealthy palatable foods to behavioural stop signals.

Design. Study 1 adopted a 2 (signal condition: stop signal vs. control) by 2 (appetite: low vs. high) between-subjects design. Study 2 adopted a 2 (signal condition: stop signal vs. control) between-subjects design with frequency to consume unhealthy palatable foods as a continuous factor.

Methods. Participants performed a task in which behavioural stop signals were either consistently (or not) presented in close temporal proximity to unhealthy palatable snack foods. Next, participants were given the opportunity to select snacks that they would like to consume.

Results. Two studies showed that participants were less likely to select unhealthy palatable foods that had been presented near stop signals, and that they selected healthy foods instead. Importantly, this reduction in choices for palatable foods was especially observed when participants' appetite was relatively high (Study 1), or when this food was part of their habit to frequently consume this food (Study 2).

Conclusion. These findings show that a short stop signal intervention in which palatable foods are presented in close temporal proximity of stop signals can reduce palatable food choices by modifying an impulsive determinant of eating behaviour.

Statement of contribution

What is already known on this subject? Exposure to unhealthy palatable foods in the environment can lead to impulsive food choices. People's habits towards unhealthy palatable foods and their current state of appetite are important determinants of such impulsive food choices. This impulsive behaviour is hard to change.

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DOI:10.1111/j.2044-8287.2012.02092.x

What does this study add?

- Linking unhealthy palatable foods to behavioural stop signals reduces choices for these foods, and increases healthy food choices.
- This effect is particularly strong when people's food choices are driven by their current state of appetite or habits.
- Behavioural stop signals foster healthy eating behaviour by modifying an impulsive determinant of behaviour.

People in industrialized countries are regularly exposed to healthy and unhealthy foods that are inexpensive and easily available (e.g., Hill & Peters, 1998; Swinburn *et al.*, 2011). One consequence of this food-rich environment is that the frequency of snacking occasions during the day has increased significantly over the last couple of decades or so (Duffey & Popkin, 2011). Moreover, many people select high-energy palatable snacks over less energy dense foods, even when they are dieting (Stroebe, 2008). The combination of a food-rich environment and the impulsive[1] tendency to select relatively unhealthy foods is likely a major contributor to the dramatic increase in rates of overweight and obesity (e.g., Wang, McPherson, Marsh, Gortmaker, & Brown, 2011), which the World Health Organization has called a global epidemic (WHO, 2000). Because changing the food-rich environment typically requires complex and time-consuming policy changes (e.g., Gortmaker *et al.*, 2011; Swinburn *et al.*, 2011), developing new psychological interventions that reduce unhealthy food choices within this environment is crucial for stopping this worrisome trend (e.g., Hill, Wyatt, Reed, & Peters, 2003).

To be effective, such interventions should focus on reducing people's consumption of palatable but high-energy foods in favour of healthier foods. That is because consumption of such palatable foods has been identified as the major cause of the increase in overweight and obesity (e.g., Goris & Westerterp, 2008; Hill *et al.*, 2003; Swinburn *et al.*, 2011). However, even though research has uncovered important cognitive determinants of disinhibited eating (e.g., Baumeister & Heatherton, 1996; Hall, 2012; Strack & Deutsch, 2004), much less is known about how to change this behaviour (Hofmann, Friese, & Wiers, 2008). Accordingly, two studies examined whether modifying an impulsive determinant of behaviour (i.e., motor impulses to obtain the foods) can be effective in reducing people's subsequent impulsive choices for palatable foods, and foster healthier food choices.

Why is it so difficult for many people to resist unhealthy palatable food? Contemporary psychological models of self-control suggest that part of the answer may be that perception of palatable foods triggers cognitive processes that facilitate approaching these foods even if this behaviour is inconsistent with people's intentions (e.g., Metcalfe & Mischel, 1999; Hofmann *et al.*, 2008; Strack & Deutsch, 2004). Specifically, one important proximal determinant of behaviour towards palatable foods is the immediate elicitation of motor programmes to obtain these foods once they are encountered (e.g., Hofmann *et al.*, 2008; Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). This impulsive determinant of behaviour exerts influence on overt behaviour particularly when people have a high appetite or frequently consume these foods as part of their habits (e.g., Aarts, 2007; Seibt, Häfner, & Deutsch, 2007; Strack & Deutsch, 2004; Verplanken & Faes, 1999). Controlling these impulsive reactions towards palatable foods appears crucial for restricting ones

[1] *Following the reflective impulsive model (Strack & Deutsch, 2004), we use the term impulsive behaviour for behaviour that is facilitated by motivational orientations (such as appetite) or associative links (such as habits).*

consumption of such foods (Hall, 2012). Indeed, individual differences in the ability to inhibit one's responses in general and towards food in particular are linked to distal outcome variables such as body weight (e.g., Batterink, Yokum, & Stice, 2010; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010).

Recent research suggests that impulsive reactions towards foods may be modified by linking stop signals to these foods (Veling & Aarts, 2009). Stop signals are cues in the environment that indicate that behaviour should be withheld (Veling & Aarts, 2011a). They have been shown to immediately inhibit any elicited motor programmes towards palatable foods even when people do not intent to inhibit such impulses (Veling, Aarts, & Papies, 2011; Veling, Aarts, & Stroebe, 2011). Because the strength of the inhibitory effect of stop signals is a function of the strength of the initially evoked impulse (e.g., Nakata *et al.*, 2006; Veling and Aarts, 2011b), stop signals should be particularly effective in inhibiting behaviour when reactions towards palatable foods are strongly evoked in the first place.

How can stop signals be used to change behaviour towards unhealthy palatable foods? Studies suggest that this may be accomplished by consistently presenting stop signals in close temporal proximity of palatable foods (Houben, 2011; Houben & Jansen, 2011; Veling, Aarts, & Papies, 2011). Consistently perceiving a specific palatable food followed by a stop signal can establish an association between that food and inhibition, so that subsequent perception of the food no longer evokes impulsive action but inhibits behaviour (Verbruggen & Logan, 2008; Veling & Aarts, 2009). Research has shown that such a stop signal intervention can reduce consumption of one specific palatable food that is provided by an experimenter (Houben, 2011; Houben & Jansen, 2011; Veling, Aarts, & Papies, 2011). However, interventions to reduce palatable food consumption can reduce quantity of consumption without reducing choices for these foods (e.g., Pliner & Mann, 2004), raising the important fundamental question whether stop signals can affect food choices. Hence, research is needed testing whether stop signals can be used to put people's impulsive selection of unhealthy food on a hold and facilitate selection of healthy foods.

Moreover, although it has been proposed before that stop signals exert their influence on behaviour by modifying an impulsive determinant of behaviour (i.e., motor impulses to act on the foods; Veling & Aarts, 2011a), research that directly examines this hypothesis is lacking. To test this hypothesis, we examined whether the effects of stop signals would materialize particularly when behaviour is strongly driven by impulsive influences. That is, if stop signals indeed modify an impulsive determinant of behaviour towards palatable foods, linking palatable foods to stop signals should modulate behaviour towards these foods when people's behaviour is determined by impulsive influences (Hofmann *et al.*, 2008; Strack & Deutsch, 2004). In Study 1 we examined the effectiveness of stop signals in reducing choices for palatable foods when people are relatively food-deprived, and are hence prone to impulsively act on palatable snack foods as a result of their appetite. In Study 2 we tested whether stop signals reduce choices for palatable foods that elicit strong motor impulses because these foods have been frequently consumed in the past and are part of food habits.

STUDY 1

In Study 1 we examined the impact of stop signals on food choices among people with different levels of appetite (i.e., the desire to eat food, felt as hunger). People often select food when they are relatively food-deprived (e.g., selecting food for lunch), and a number of research findings suggest that under such circumstances people respond impulsively to palatable foods. For instance, perception of palatable foods immediately prepares responses to obtain these foods among participants who are food-deprived (Seibt *et al.*, 2007). This finding is consistent with the fact that the motor system is closely tied to the reward system (e.g., indirectly or through direct projections of midbrain dopaminergic neurons to the motor cortex; for example, Kapogiannis, Campion, Grafman, & Wassermann, 2008; Yalachkov, Kaiser, & Naumer, 2010), and the reward system has been shown to be very responsive to perception of palatable foods when people are food-deprived (Siep, Roefs, Roebroeck, Havermans, Bonte, & Jansen, 2009). Moreover, high appetite individuals impulsively purchase more foods than satiated individuals (Gilbert, Gill, & Wilson, 2002). Hungry individuals are also prone to choose (e.g., Tuorila, Kramer, & Engell, 2001), and purchase (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009) high-energy (palatable) foods over less energy dense foods.

To test whether such impulsive choices for palatable foods can be reduced among people with a high versus low appetite, we first linked palatable foods (and filler objects) to behavioural stop signals (i.e., do not touch the object; stop signal condition), or not (control condition). Next, participants could select unhealthy palatable snacks that had been presented during the go/no-go task (i.e., the four experimental palatable foods), unhealthy foods that had not been presented before (i.e., four new palatable foods), and eight healthy foods. Our primary dependent variable was the choices for the experimental palatable foods. We expected reduced choices for experimental unhealthy palatable foods among high appetite participants in the stop condition compared to the control condition.

Method

Participants and design

Study 1 included 79 young adults (49 women; mean age = 21.38, *SD* = 2.91; mean Body Mass Index = 22.00, *SD* = 2.75). We invited a non-clinical sample because the research involves a first test of the effect of stop signals on food choice. Participants in both studies received a small payment for their participation. We employed a 2 (signal condition: stop vs. control) by 2 (appetite: high vs. low) between-subjects design. Participants were randomly assigned to a signal condition. Furthermore, participants were recruited for the study either before lunch (high appetite condition) or after lunch (low appetite condition; e.g., Seibt *et al.*, 2007; Veltkamp, Aarts, & Custers, 2008). Accordingly, we examined whether stop signals are effective under everyday circumstances where people's appetite is relatively high (i.e., before lunch; e.g., Blundell, Lawton, Cotton, & MacDiarmid, 1996; Graaf, Jas, Kooy, & Leenen, 1993).

Stimuli

As food stimuli we used pictures of 16 snack foods that were photographed for purpose of the present study (see Figure 1). We focused our examination on snack foods (i.e., foods that are typically consumed between regular meals), because snack food consumption is considered an important contributor to weight gain (e.g., Graaf, 2006; Jahns, Siega-Riz, & Popkin, 2001; Zizza, Siega-Riz, & Popkin, 2001). The perceived palatability (ranging from not at all tasty to very tasty) and healthiness (ranging from not at all healthy to very healthy) of these snacks was assessed (on 9 point scales) in an independent sample of participants (*N* = 56). Palatable unhealthy snacks (i.e., potato chips, chocolate, muffin, salted nuts,

Figure 1. Stimuli as presented in the choice task. Participants could select the foods by touching them.

cheese balls, M&M's, chocolate chip cookies, cookies) were perceived as more palatable ($M = 6.10$; $SD = 1.00$) compared to the healthy snacks (i.e., carrots, gingerbread, health bars, fruit salad, apple, muesli bars, crackers, rice cake's; $M = 5.40$; $SD = 1.11$; $F(1,55) = 14.18$, $p < .001$, $\eta_p^2 = .21$), and palatable unhealthy snacks were perceived as unhealthy ($M = 2.55$; $SD = .96$) compared to the healthy snacks ($M = 6.57$; $SD = 0.80$; $F(1,55) = 349.35$, $p < .001$, $\eta_p^2 = .94$).

Procedure

After receiving informed consent participants were told that they participated in a study examining the usability of a touch-screen for future studies on consumer choice behaviour, and that instructions for the (ostensibly) unrelated tasks would appear on screen. The aim of the first task was to familiarize participants with the procedure of choosing objects among an array of 16 objects by touching them on the touch screen (i.e., in a similar fashion as they would be choosing the snacks later) and to distract them from the true purpose of the study. Participants were asked to select eight different objects from an array of 16 objects that they would like to obtain and that they could choose objects by touching them on screen. These objects were unrelated to food.

Next, participants received the stop signal manipulation. They were instructed that familiar objects would again be presented on screen. However, this time each object would be presented in the middle of the screen one by one and participants were asked to touch the objects, or not, depending on a tone that was presented during presentation of the object. They were instructed to touch the object when a high (or low; counterbalanced across participants) tone was presented, and refrain from responding when a low (or high) tone was presented. Each trial started with a fixation point for 500 ms. Then, a middle pitched tone was presented immediately followed by the object. After the object had been displayed on screen for 500 ms either a high or low tone was presented, and participants could touch the object or not, while the object remained on screen for 1500 ms. When participants responded correctly the background of the screen turned green, and if they responded incorrectly the background turned red. In the case of a correct or incorrect non-response the background colour changed 1500 ms after presentation of the object. Next, a blank screen appeared for 500 ms followed by the message that participants could press the space bar to start the next trial.

The go/no-go task consisted of eight blocks of 12 trials. Within each block eight pictures of filler objects (e.g., pen, light bulb, and scissors) and four experimental palatable foods were presented. The number of touch responses was 50% within each block. Importantly, in the control condition foods were always followed by a signal to touch the object whereas in the stop signal condition foods were always followed by a signal to refrain from touching the object. We counterbalanced presentation of two sets of four palatable unhealthy foods across participants. Thus, participants either consistently responded (control condition) or refrained from responding (stop condition) to four experimental palatable foods.

The third task contained our dependent measure of food choice. We reminded participants that people sometimes consume foods between their regular meals (e.g., during a trip, while watching television, during a party), and that they would be asked to select eight of such foods among an array of 16 foods. Participants were instructed that they should chose foods that they would like to consume and to take home for consumption. This array also contained the four experimental palatable foods. We used a touch screen to assess participants' choice behaviour, as reaching out and touching objects on a touch screen provides an intuitive way to interact with the environment. Moreover, vending machines in university cafeterias often contain clearly visible snacks that can be selected by pressing the appropriate buttons. Furthermore, as people often make food choices under some time pressure, participants were instructed to make their choices within a time limit of 15 s. After this third task and a filler task we assessed people's level of appetite on a nine-point Likert scale (ranging from not at all to very high). Finally, participants filled-out demographic questions, and they were thanked and paid for their participation.

Results

Manipulation check

Self-reported appetite was higher in the high appetite condition (M = 6.27; SD = 1.89) compared to the low appetite condition (M = 5.03; SD = 2.25), $F(1,77) = 7.05, p < .05, \eta_p^2 = .08$.

Main analyses

Next, we performed an analysis of variance (ANOVA) with signal condition (control vs. stop) and appetite (high vs. low) as between-subjects factors and the number of experimental palatable foods chosen as the dependent variable. This analysis revealed a

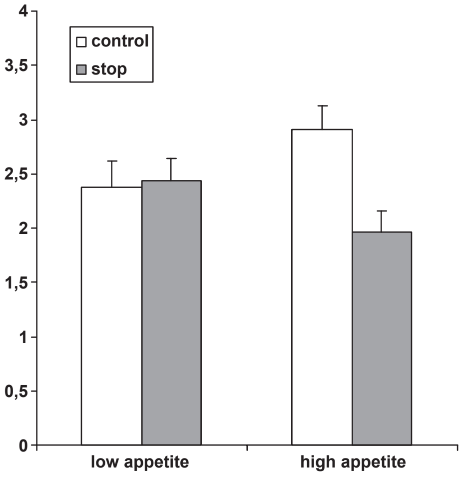

Figure 2. Mean number of choices for experimental unhealthy palatable foods as a function of signal condition and appetite. Error bars = *SE*.

main effect of signal condition, $F(1, 75) = 4.35$, $p < .05$, $\eta_p^2 = .06$, which was qualified by the predicted interaction between signal condition and appetite (see Figure 2), $F(1, 75) = 5.83$, $p < .05$, $\eta_p^2 = .07$. Within the control condition greater appetite was associated with more choices for the experimental palatable foods, $F(1, 75) = 3.99$, $p < .05$, $\eta_p^2 = .05$. A marginally significant effect of appetite in the opposite direction was found within the stop condition, $F(1, 75) = 2.96$, $p = .07$, $\eta_p^2 = .04$. Moreover, within the high appetite condition participants in the stop condition chose fewer experimental palatable foods than participants in the control condition, $F(1, 75) = 11.77$, $p < .01$, $\eta_p^2 = .14$. This effect was absent in the low appetite condition, $F < 1$.

Additional analyses

To assess whether the reduction in choices for the palatable foods in the stop signal condition led to an increase in healthy food choices, we performed an additional ANOVA with choices for the relatively healthy foods as dependent variable and signal condition and appetite as between-subjects factors. The signal condition by appetite interaction was significant, $F(1, 75) = 4.40$, $p < .05$, $\eta_p^2 = .06$. High appetite participants chose more healthy foods in the stop condition ($M = 3.74$; $SD = .1.51$) compared to the control condition ($M = 2.50$; $SD = 1.23$), $F(1, 75) = 9.88$, $p < .01$, $\eta_p^2 = .12$. This effect was absent among low appetite participants ($M_{stop} = 3.17$; $SD_{stop} = .86$; $M_{control} = 3.18$; $SD_{control} = 1.56$), $F < 1$. A similar ANOVA with new unhealthy palatable foods as dependent variable showed no significant effects, *F*s < 1.

Discussion

Results of Study 1 show that presenting palatable foods in close temporal proximity of stop signals reduces subsequent choices for these foods. Moreover, this reduction was only found when participants' appetite was relatively high and hence people were particularly prone to impulsively select palatable foods. Indeed, the results in the control condition conceptually replicate previous work by revealing that participants selected more unhealthy palatable foods when their appetite was relatively high (Nederkoorn *et al.*, 2009; Tuorila *et al.*, 2001). Notably, and in line with our prediction, this effect of appetite was absent when the unhealthy palatable foods had been associated with behavioural stop signals. Finally, results revealed that among high appetite participants, presentation of stop signals near unhealthy palatable foods was effective in reducing participants' choices for these foods.

The reduction in choices for experimental palatable foods among relatively high appetite participants in the stop signal condition compared to the control condition is consistent with the hypothesis that presentation of stop signals instigated motor inhibition that suppressed the impulse towards the foods (e.g., Stinear, Coxon, & Byblow, 2009; Veling, Aarts, & Papies, 2011). The motor inhibition may have become attached to the foods such that perception of the food in the choice situation reinstated the motor inhibition and reduced choices for these foods (Veling & Aarts, 2009; Verbruggen & Logan, 2008). Because this motor inhibition does not occur when foods do not elicit strong impulses (i.e., among relatively low appetite participants; Seibt *et al.*, 2007; Veling and Aarts, 2011a,b) the end result is lower choices of experimental palatable foods for relatively high appetite participants compared to low appetite participants in the stop signal condition (for a related finding see Veling & Aarts, 2009).

The results of Study 1 suggest that stop signals can be an effective tool to reduce unhealthy food choices under conditions where participants are particularly likely to impulsively select such foods. What is more, this reduction in choices for the experimental palatable foods led to more choices for healthy foods. These findings suggest that stop signals are particularly effective in changing unhealthy food choices when impulsive determinants strongly guide behaviour (Hofmann *et al.*, 2008; Strack & Deutsch, 2004). In Study 2 we aimed to replicate and extend these findings by testing whether stop signals reduce choices for palatable foods among people who impulsively act on these foods because they have frequently selected these foods in the past and thus these choices have become part of their food habits (Aarts & Dijksterhuis, 2000; Danner, Aarts, & Vries, 2008).

STUDY 2

Research has shown that frequency of past behaviour towards unhealthy palatable foods is a strong predictor of future behaviour towards these foods (e.g., Pereira, Kartashov, Ebbeling, Van Horn, & Slattery, 2005; Verplanken & Faes, 1999), and formation of intentions to reduce consumption of these foods or eat more healthily in general are often ineffective in reducing consumption of frequently consumed palatable foods (e.g., Elfhag & Rössner, 2005; Mann, Tomiyama, Westling, Lew, Samuels, & Chatman, 2007; Verplanken & Faes, 1999; for a recent meta-analysis see Adriaanse, Vinkers, Ridder, Hox, & Wit, 2011). One factor that may contribute to this difficulty is that repeated selection of a particular food creates a habit in which a strong link is established between the perception of the food and behavioural programmes that are instrumental in obtaining the food (Aarts & Dijksterhuis, 2000). Such links may become particularly strong in the case of palatable foods as common ingredients in such foods (e.g., sugar) can function as rewards (e.g., Epstein, Carr, Lin, & Fletcher, 2011) that reinforce such stimulus-response links through basic learning mechanisms (e.g., Bouton, 2011; Thorndike, 1911). Once a link between food and behavioural programmes to obtain the food is firmly established mere perception of the food will evoke impulses to act on the food (e.g., Hofmann *et al.*, 2008; Strack & Deutsch, 2004; Yalachkov *et al.*, 2010). Because stop signals should modify and inhibit these impulsive reactions, we expect that consistently presenting stop signals near specific palatable foods will reduce choices for these foods among people that frequently selected these foods in the past.

To test this hypothesis we again manipulated whether palatable foods were linked to stop signals, but we also measured people's past frequency of selecting these foods as an indicator of habitual food choice. We expected that participants' selection of snacks in the control condition would be strongly guided by this frequency measure (e.g., Danner *et al.*, 2008; Verplanken, 2006; Verplanken & Faes, 1999). Moreover, we expected the stop signal manipulation would reduce choices for experimental palatable foods among participants that have frequently selected these foods in the past.

Method

Participants and design

Study 2 included 44 young adults (27 women; mean age = 21.50, *SD* = 2.90; mean Body Mass Index = 21.61, *SD* = 2.41). We employed a 2 (signal condition: control vs. stop) between-subjects design, and included frequency of past behaviour as a continuous variable.

Frequency of past behaviour measure

To assess participants' past behaviour toward the different snack foods, participants were asked to rate how often they consume each type of snack on a 9-point scale ranging from *not at all* (1) to *very often* (9) (e.g., Aarts, 2007; Danner *et al.*, 2008; Pereira *et al.*, 2005; Verplanken & Faes, 1999). The frequency measure was constructed by averaging the responses to these questions for the four experimental palatable foods. Frequency to consume the experimental palatable foods did not differ between the signal conditions (overall mean = 4.54; *SD* = 1.51), $F<1$.

Procedure

Study 2 was similar to Study 1 with three important changes. First, we aimed to simulate food choices during everyday experiences of distraction (e.g., while engaged in a conversation) by asking participants to make their food choices while they were monitoring the number of occurrences of a specific letter (i.e., presented within a continuous stream of letters) spoken aloud by a recorded voice during the choice task. Examining the effects of stop signals during such mundane distraction is particularly interesting in this study, as people have been shown to strongly rely on their frequently performed past behaviour in such circumstances (e.g., Aarts & Dijksterhuis, 2000; Hofmann *et al.*, 2008). Second, we assessed people's frequency of selecting the experimental palatable foods at the end of the session. Finally, because this frequency of past behaviour measure may be related to palatability and healthiness ratings of the foods, we also assessed palatability (ranging from not at all tasty to very tasty) and healthiness (ranging from not at all healthy to very healthy) of each food on 9-point Likert scales.

Results

Main analyses

We analysed choices for the experimental palatable foods in the General Linear Model (GLM) as a function of signal condition (control vs. stop) and including the standardized

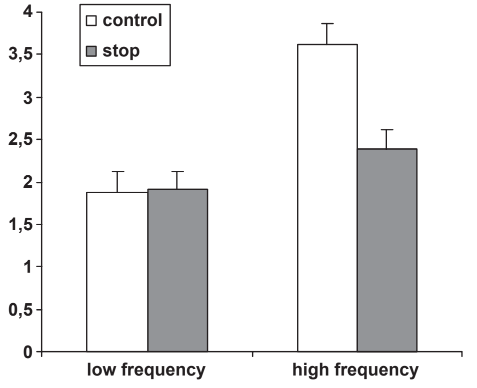

Figure 3. Mean number of choices for experimental unhealthy palatable foods as a function of signal condition for participants with low frequency of past behaviour scores (1 *SD* below the mean) and high frequency scores (1 *SD* above the mean). Error bars = *SE*.

frequency of past behaviour measure as a continuous factor. This analysis yielded main effects of signal condition, $F(1, 40) = 6.90$, $p < .05$, $\eta_p^2 = .15$, and frequency, $F(1, 40) = 22.08$, $p < .01$, $\eta_p^2 = .36$. Importantly, these effects were qualified by the predicted interaction between these factors, $F(1, 40) = 7.18$, $p < .05$, $\eta_p^2 = .15$ (see Figure 3). To explore this interaction, we examined the effect of signal condition for participants with relative low frequency scores (1 *SD* below the mean of the standardized frequency measure) and for participants with relative high frequency scores (1 *SD* above the mean of the standardized frequency measure; see Aiken & West, 1991 for this regression analysis). With this estimation procedure we could test the effect of signal condition for participants with high and low frequency scores separately without conducting a median split and while retaining all observations in the analysis.

Among participants that scored relatively high on the frequency measure (1 *SD* above the mean) we observed the predicted effect of signal condition, $F(1, 40) = 14.31$, $p < .01$, $\eta_p^2 = .26$, showing that choices for the palatable unhealthy foods were reduced after these foods had been associated with stop signals. This effect of signal condition was absent among participants with relatively low frequency measure scores (1 *SD* below the mean), $F<.1$ (see Figure 3). Moreover, the frequency measure was positively and significantly related to choices for the foods in the control condition, $r(21) = .72$, $p < .01$, but not significantly related to choices in the stop signal condition, $r(23) = .34$, $p = .11$.

Palatability and healthiness ratings of the foods were unaffected by signal condition. However, the frequency measure of past behaviour correlated with palatability ratings of the foods, $r(44) = .60$, $p < .01$. Controlling the analyses for palatability did not affect the reliability or the pattern of the results reported above (test for the interaction effect, $F(1, 39) = 8.02$, $p < .01$, $\eta_p^2 = .17$). Frequency was not correlated with healthiness ratings of the foods, $r(44) = -.06$, $p = .69$.

Additional analyses

To assess whether the reduction in choices for the palatable foods in the stop condition led to an increase in healthy food choices, we performed an additional GLM with choices for the relatively healthy foods as dependent variable and frequency of past behaviour as a continuous predictor. The signal condition by frequency interaction was marginally significant, $F(1, 40) = 3.58$, $p = .07$, $\eta_p^2 = .09$. Participants with high frequency scores towards the palatable foods chose more healthy foods in the stop condition ($M = 3.33$; $SE = .40$) compared to the control condition ($M = 1.98$; $SE = .42$), $F(1, 40) = 5.48$, $p < .05$, $\eta_p^2 = .12$. This effect was absent for participants with low frequency scores ($M_{no\text{-}go} = 3.53$; $SE_{no\text{-}go} = .37$; $M_{go} = 3.76$; $SE_{go} = .45$), $F<1$. An analysis with the number of new palatable foods as a dependent variable yielded no significant effects, Fs<1.

Discussion

Consistent with previous work (e.g., Danner *et al.*, 2008; Verplanken & Faes, 1999), Study 2 revealed that the frequency of past behaviour towards palatable foods strongly predicted choices for unhealthy palatable foods in the control condition. Importantly, this relation was no longer significant after the unhealthy palatable foods had been repeatedly linked with behavioural stop signals. Furthermore, the results show that presenting stop signals near unhealthy foods reduced subsequent choices for these foods among people who have frequently consumed these foods in the past as part of their habits. These findings suggest that people's difficult to change existing food choices (e.g., Danner, Aarts, Papies, & de Vries, 2011) can be changed by linking foods to behavioural stop signals. More generally, the results further support the hypothesis that stop signals can change choices for palatable foods when these choices are strongly influenced by impulsive influences.

GENERAL DISCUSSION

Research showing that a relatively short stop signal intervention as employed here can be effective in reducing consumption of unhealthy drinks and foods is quickly accumulating (Houben, 2011; Houben & Jansen, 2011; Houben, Nederkoorn, Wiers, & Jansen, 2011; Veling , Aarts, & Papies, 2011). However, much needs still to be learned about the workings of stop signals. For instance, to date it has been unclear whether stop signals can affect behaviour beyond quantity of consumption, and how stop signals exert their influence on behaviour. The present work first reveals that effects of stop signals are not constrained to reducing quantity of consumption, but can even reduce choices for specific foods (cf. Pliner & Mann, 2004). Considering that unhealthy consumption behaviour is not only a matter of quantity of consumption, but also quality of consumption (e.g., Stroebe, 2008), the present studies highlight the great potential of using stop signals to improve health behaviour.

Moreover, the present studies provide new insight into the mechanism by which stop signals alter unhealthy consumption. Specifically, by employing two moderators in our studies that are known to strengthen impulsive behaviour (i.e., appetite and frequency of past behaviour; Strack & Deutsch, 2004), we were able to show that stop signals exert their influence under conditions where behaviour is more likely to be guided by impulsive influences. These findings strongly support the notion that stop signals affected the food choices because they changed an impulsive determinant of behaviour (i.e., motor impulses to act on the foods; Veling, Aarts, & Papies, 2011; Veling & Aarts, 2011b). The current findings are thus consistent with the understudied hypothesis that changing an impulsive determinant of behaviour can lead to a change in overt health behaviour (Hofmann *et al.*, 2008; Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011).

Study 2 further showed that the reduction in choices for the foods by the stop signal manipulation was not driven or accompanied by a decrease in the palatability ratings of these foods. Although stop signals have been found to decrease implicit evaluations of objects (e.g., Houben *et al.*, 2011), the explicit and perhaps memory-based palatability ratings of foods appear insensitive to the stop signal manipulation. Thus, stop signals may leave explicit knowledge about the tastiness of foods unaffected, which further supports the hypothesis that stop signals modified food choices by changing an impulsive (rather than reflective) determinant of behaviour towards the foods (e.g., Strack & Deutsch, 2004).

Notably, also from an applied perspective, across both studies the reduction in choices for the experimental palatable foods did not lead to a greater selection of new palatable foods, but to a greater selection of healthy foods instead. The fact that the number of healthy foods to choose from was equal to the number of palatable foods may have contributed to this interesting effect. The present context, which contained a variety of healthy and unhealthy foods, appears in line with a number of ecological food choice contexts (e.g., grocery stores, canteens, buffets). Future research may further examine the effect of stop signals across different food choice contexts. For instance, it would be interesting to test whether stop signals do not only shift the balance from unhealthy food choices to more healthy choices, but may also reduce the number of choices when people can choose as many foods as they like. Moreover, research is needed to test whether the stop signal intervention can affect food choices in less controlled (laboratory) set-ups. The present work suggests that it is worthwhile to test these questions in the future.

Acknowledgements

The work in this paper was financially supported by grants from the Netherlands Organization for Scientific Research (NWO VICI-grant 453-06-002), and from the Netherlands Organisation for Health Research and Development (ZONMW-grant 11510001).

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Received 21 December 2011; revised version received 3 April 2012