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## From cookies to carrots; the effect of inhibitory control training on children's snack selections



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### ABSTRACT

Children consume too much sugar and not enough fruit and vegetables, increasing their risk of adverse health outcomes. Inhibitory control training (ICT) reduces children's and adults' intake of energy-dense foods in both laboratory and real-life settings. However, no studies have yet examined whether ICT can increase healthy food choice when energy-dense options are also available. We investigated whether a food-specific Go/No-Go task could influence the food choices of children aged 4–11, as measured by a hypothetical food choice task using healthy and unhealthy food images printed on cards. Participants played either an active game (healthy foods = 100% go, unhealthy foods = 100% no-go; Studies 1 & 2), a food control game (both healthy and unhealthy foods = 50% go, 50% no-go; Studies 1 & 2) or a non-food control game (sports equipment = 100% go, technology = 100% no-go; Study 2 only) followed by the choice task. In Study 2, food card choices were also measured before training to examine *change* in choices. A post-training real food choice task was added to check that choices made in the card-based task were representative of choices made when faced with real healthy and unhealthy foods. Overall, the active group chose the greatest number of healthy food cards. Study 2 confirmed that this was due to increases in healthy food card choice in this group only. Active group participants chose a greater number of healthy foods in the real food choice task compared to children in the non-food control group only. The results are discussed with reference to methodological issues and the development of future healthy eating interventions.

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### 1. Introduction

The average European child does not consume a healthy diet. In the UK, only 10% of boys and 7% of girls eat the recommended amount of fruit and vegetables per day (Public Health England, 2014), compared to 23.5% of children across Europe (Lynch et al., 2014). Concurrently, British children ingest up to three times the guideline World Health Organization daily sugar allowance (House of Commons Health Committee, 2015) which comes primarily from sugary beverages, confectionery, biscuits and cakes (Public Health England, 2015a). Such foods are superfluous to a healthy diet (Public Health England, 2015a) and can contribute to the development of dental carries, obesity, cognitive impairments and diseases such as diabetes (Noble & Kanoski, 2016; Public Health

England, 2015b). Given that dietary habits are consolidated in childhood, it is imperative that changes are made during this period (Haire-Joshu & Tabak, 2016).

Current healthy lifestyle interventions typically depend upon education and top-down self-regulation of behavior (Sobol-Goldberg, Rabinowitz, & Gross, 2013). However, children's top-down control capacities are immature compared to the bottom-up processes that may motivate them to consume energy-dense foods (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Ha et al., 2016; Nigg, 2017). Furthermore, emphasizing the health benefits of foods can have the adverse effect of decreasing consumption amongst children (Maimaran & Fishbach, 2014) whilst palatability of foods remains a strong factor in food selection (Nguyen, Girgis, & Robinson, 2015). It has previously been noted that educational campaigns may be ineffectual due to their neglect of the automatic processes that contribute towards behavior (Marteau, Hollands, & Fletcher, 2012) and dual-process models

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propose that behavior is the outcome of implicit/automatic processes as well as deliberate 'top-down' control (e.g., Hofmann, Friese, & Strack, 2009). Indeed, a wide body of research points towards the contribution of implicit processes such as high reward-sensitivity, which then interacts with individual variations in inhibitory control to predict the onset and maintenance of over-eating and obesity (Bartholdy, Dalton, Daly, Campbell & Schmidt, 2016; Brockmeyer, Sinno, Skunde et al., 2016; Lawrence, Hinton, Parkinson, & Lawrence, 2012; Meule & Platte, 2016; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Saunders & Robinson, 2013; Stice, Lawrence, Kemps, & Velting, 2016).

This has led to calls for an alternative approach to tackling unhealthy eating behavior by targeting more automatic, implicit processes (Marteau et al., 2012). One such approach uses food-specific inhibitory control training (ICT) to train automatic control over responses to foods in Go/No-Go or Stop Signal tasks (Allom, Mullan, & Hagger, 2016; Houben & Jansen, 2015; Jones et al., 2016; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015a). Participants are trained to perform a motor response (keyboard press) when presented with a go signal and to inhibit this response when presented with a stop (or no-go) signal. By consistently pairing unhealthy stimuli (e.g., chocolate, alcohol) with motor inhibition, ICT has been found to reduce selection and consumption of unhealthy foods and beverages in adult populations (Velting, Aarts, & Stroebe, 2013; Allom et al., 2016; Jones et al., 2016; but see also; Smith, Dash, Johnstone, Houben, & Field, 2017) and has even led to weight loss in overweight young adults and community samples (Velting, van Koningsbruggen, Aarts, & Stroebe, 2014; Lawrence et al., 2015b).

The mechanisms behind such training are thought to be twofold; firstly, consistently associating a stimulus with inhibition encourages the development of stimulus-stop associations, helping to automatize inhibitory control in response to that stimulus (Lenartowicz, Verbruggen, Logan, & Poldrack, 2011; Verbruggen & Logan, 2008; Verbruggen, Best, Bowditch, Stevens, & McLaren, 2014). Secondly, consistently inhibiting responses to a rewarding stimulus has the effect of devaluing that stimulus (Chen, Velting, Dijksterhuis, & Holland, 2016; Houben, Havermans, Nederkoorn, & Jansen, 2012; Lawrence et al., 2015b; Velting, Holland, & van Knippenberg, 2008). These findings suggest that ICT could boost impulse control towards food (automatic motor inhibition) and reduce reward sensitivity, two processes that contribute to poor dietary choices.

Despite evidence that obesity and intake of energy-dense foods in children is also associated with poor inhibitory control (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006) and high reward-sensitivity (Bruce et al., 2010), little research to date has investigated the impact of ICT on children's eating behavior. One study found that children consumed fewer calories after playing an ICT game in which images of jelly sweets were paired with stop signals relative to children who were trained to stop to non-food images (Folkvord, Velting, & Hoeken, 2016). As well as consuming fewer of these jelly sweets post-training, the effects also generalized to milk chocolate shells. Another study found that non-computerized ICT (in the form of a "Simon says" style game played in the classroom) decreased children's intake of a food paired with response inhibition (Jiang, He, Guan, & He, 2016).

However, children in these studies were only trained to inhibit to unhealthy foods and were only provided with such foods after training; healthy foods were not included in these experiments. It is therefore unknown whether ICT can also be used to increase healthy food selection and intake in children whilst simultaneously decreasing unhealthy food selection and intake. Some studies with adults have used training tasks that paired healthy foods with a go response in addition to pairing unhealthy foods with a no-go

response (Adams, Lawrence, Verbruggen, & Chambers, 2017; Lawrence et al., 2015b). It would be particularly beneficial if food inhibition training could be used to simultaneously increase the intake and choice of healthy foods and decrease that of unhealthy foods in children. Furthermore, whilst previous research has examined the effects of training on children's ad libitum intake of a small range of energy-dense foods (often only two or three options; Folkvord et al., 2016; Jiang et al., 2016), no studies have yet looked at how ICT affects children's choices when faced with a wider range of foods. Research with adults suggests that ICT can be used to increase healthy (relative to unhealthy) food selection when faced with a range of healthy and unhealthy snacks (Velting et al., 2013); the current series of studies sets out to investigate whether ICT can be used to increase the number of healthy snacks relative to unhealthy chosen by children in a similar paradigm.

## 2. Study 1

The principal aim of this study was to determine whether ICT can encourage healthier snack choices in primary school children. Whilst many previous studies have demonstrated that ICT can be used to reduce unhealthy food intake and selection in adults, the effects of training on children's food choices has yet to be examined. In Study 1, we examined the choices children made in a hypothetical shopping task after playing either an active (healthy food = go; unhealthy food = stop) or a control (all foods = 50% go, 50% stop) ICT task based on the Go/No-Go paradigm. This control task is similar to that used by Houben and Jansen (2011) and was selected on the assumption that inconsistent pairings between each food stimulus and response type would prevent the development of consistent stimulus-response associations whilst still controlling for food cue exposure. In both tasks, we used happy and sad face emoticons as the go and no-go signals, respectively. This aspect of the training incorporated an evaluative conditioning component and was based on previous findings that pairing energy-dense foods with negatively valenced images reduces favorable evaluations of such foods and encourages selections of other available options (Hensels & Baines, 2016; Hollands, Prestwich, & Marteau, 2011; Velting, Aarts, & Stroebe, 2011). As such, the inclusion of emotive go and no-go signals has the potential to strengthen training effects.

In line with findings in adults (Velting et al., 2013), we expected children to select a greater number of healthy foods over unhealthy snacks after playing the active game compared to the control task. Hunger was also measured to ensure that the two groups did not significantly differ on this measure, which has been found to affect training effects in adults (Velting et al., 2013).

Study 1 consisted of three separate experiments following the same one-way, between-subjects design with some minor adjustments between samples (see below). Experiments were conducted in primary schools by groups of trained undergraduate Psychology students and the data sets from each experiment were combined in final analyses to increase the power of the study. Experiment was also added as a between-subjects factor to investigate whether the effect of training on food choices differed between the three samples.

## 3. Method

### 3.1. Participants and design

Ethical approval was obtained from the Psychology Research Ethics Committee at the University of Exeter. Primary schools in the Exeter area were invited to participate and consenting schools then distributed parental consent letters. At the time of study design, no

other studies examining the effects of ICT in children had been published; as such we aimed for 25 participants per group within each experiment, based on the sample size of similar studies conducted in adults (Houben & Jansen, 2011). A sensitivity analysis (G-Power 3.1.9.2) revealed that for the combined sample of all three experiments, the minimum detectable effect size ( $d$ ) for the effect of condition on food choice would be 0.23 ( $\alpha = 0.05$ , power = 0.80).

Consent forms were returned for 145 children (75 female) aged 5–11 years ( $M = 7.66$ ,  $SD = 1.69$ ) from five different schools in Devon across the three samples. The study was of a one-way, between-subjects design with children being randomly assigned to either the active ( $n = 73$ ) or control condition ( $n = 72$ ).

### 3.2. Materials and measures

#### 3.2.1. Go/No-Go training task

The task was a modified variant of the Go/No-Go task based on the paradigm designed by Lawrence et al. (2015b). In this paradigm, individual stimuli (food images) are presented on each trial and are paired with either a go or a no-go signal. Participants are required to make a motor response (key press) upon the presentation of the go signal but to withhold this response when presented with the no-go signal. Both the active and control task consisted of four blocks of 32 trials. The duration of each trial was fixed at 1250 ms, followed by an inter-trial interval of 1250 ms. At the end of each block, accuracy (percentage) and response time (in ms) scores were presented.

Both tasks contained the same 16 food stimuli. Half of these (eight images) were of healthy foods (HF; e.g., apples, blueberries) and half were of unhealthy foods (UF; e.g., chocolate buttons, crisps – see supplementary materials). Pictures were obtained from search engines and from the image set used by Lawrence et al. (2015b). On each trial, a food picture was paired with a go or a no-go signal. The go signal was one of three happy face emoticons whilst the no-go signal was one of three sad face emoticons. Emoticons were used as they provided a simple and intuitive rule for children to follow (i.e., “press for foods that appear with happy faces, don’t press for foods that appear with sad faces”). The use of emoticons as signals also added an evaluative conditioning component to the training (whereby unhealthy foods are paired with negative affective images and healthy foods with positive images) to potentially strengthen training effects. Evaluative conditioning has previously been shown to reduce unhealthy food choice in adults (e.g., Hollands et al., 2011). The use of three different go and no-go signals was based on the observation that using multiple no-go signals increases the learning of direct stimulus-response associations rather than stimulus-signal associations (Best, Lawrence, Logan, McLaren, & Verbruggen, 2016; Bowditch, Verbruggen, & McLaren, 2016).

In the active task, HF stimuli were consistently paired with go signals and UF stimuli were consistently paired with no-go signals (see Fig. 1); in the control task, all food stimuli were paired with both signal types equally. Each food stimulus was presented with two different emoticons throughout the task (i.e., two variants of the same signal type in the active task; one of each signal type in the control task) in order to reduce the contingency between stimuli and specific stop signals (Best et al., 2016; Bowditch et al., 2016). Stimuli in the control condition were automatically paired with two different signals (one go and one no-go signal); therefore, we ensured that food stimuli in the active task were also paired with two different signals. Signals appeared equally in one of the four corners of the screen near to the stimulus to encourage attention to the entire picture frame area.

The same tasks were used for Experiments 1 and 2. Due to child

feedback, one of the go signals was changed for Experiment 3 as children were unsure of the valence of the signal (this particular emoticon showed lots of pointy teeth in its smile which some participants found confusing). A pilot study on children’s food preferences before Experiment 3 also revealed that tomatoes received very low ratings from children and so this stimulus was replaced by an image of grapes.

#### 3.2.2. Hunger scale

Hunger was measured using a Likert scale (9-point in Sample 1, 11-point in Samples 2 and 3; adapted from Veling et al., 2013). Visual and descriptive aids were used along the scale with lower numbers representing “Very Full” (happy face) and higher numbers representing “Very Hungry” (sad face). The faces used as visual aids were different from those used as signals during training (see supplementary materials).

#### 3.2.3. Food choice shopping task

Sixteen images of food were printed, laminated and cut into separate cards (approximately  $7 \times 10$  cm each). Half of these (eight images) were of HF stimuli and half were of UF stimuli. Images were sourced from internet search engines and a validated food picture database (Blechert, Meule, Busch, & Ohla, 2014). Some of the images were of foods that had also been included in the training – in Experiments 1 and 3, half of the food cards (eight images) were of trained foods and half were of novel foods that had not appeared in the Go/No-Go task whereas in Experiment 2, three-quarters of cards (12 images) were of trained foods and one-quarter (four images) were of novel foods.<sup>1</sup> If cards depicted trained foods, a different exemplar to that shown in training was used.

Cards were laid out on the desk in a random order. Children were given one minute to pick the eight foods they would most like to eat and put them in their shopping basket. This time limit was imposed in order to encourage fast responding (i.e., to encourage choices driven by reward-based impulses) and children were warned when they only had 30 s remaining. They were also informed that they would be given one of these foods as a reward to take home in order to encourage valid choices (Schonberg, Bakkour, Hover, Mumford, & Poldrack, 2014). The number of HF choices made was covertly recorded.

### 3.3. Procedure

An identical procedure was followed for all three samples. Children completed the experiment in the school environment in small groups of 1–4 children. They were taken to a separate room away from the rest of the class and invited to play a computer game. Computers were placed so that children could not see the screens of other children. They were given verbal and written instructions on how to play the Go/No-Go task, with the training framed as an online game in which they had to help their parents collect the right foods for dinner. Children completed a practice block (responses not recorded) to check that they understood the task. Children were given accuracy and reaction time (RT) feedback at the end of the practice block and each experimental block. Following the practice block, children completed the four blocks of the training task, with the instructions that they should do so as quickly and as accurately as possible.

After the training, children filled out the hunger scale. They were then asked to play the food choice shopping game. Children

<sup>1</sup> This minor modification was for exploratory purposes for a student project. However, we do not focus on this in the current paper as the individual experiments had small sample sizes and were relatively underpowered.

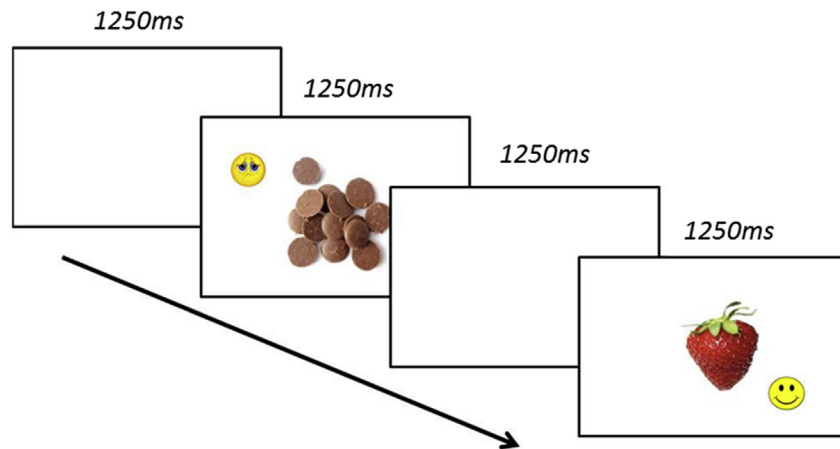


Fig. 1. Trial and inter-trial interval sequence for active condition.

were given their own set of food cards and a small shopping basket to place their selections in. They completed the task separately from the other children in the group. The experimental session concluded with children being debriefed about the study. At the end of the school day, children were given one of their choices from the shopping game to take home. Children were given a HF reward if four or more of their choices in the game were healthy. Children who selected five or more UF choices were given one of these foods as a reward to take home.

## 4. Results

The complete SPSS data file is deposited in the University of Exeter's data repository, Open Research Exeter (ORE).<sup>2</sup>

### 4.1. Preliminary analyses

Accuracy and reaction time data were checked in order to identify participants who should be excluded on the basis of poor performance. Exclusion criteria included average reaction times that were greater than three standard deviations from the group mean (no exclusions) or less than 60% overall accuracy. A fixed criterion was used in order to avoid excluding younger age groups based on expected lower accuracy scores for these participants. A total of three participants were excluded on this basis, resulting in a final sample size of 142 participants (74 female) aged 5–11 ( $M = 7.69$ ,  $SD = 1.67$ ) with 72 in the active group and 70 in the control group.

Randomization checks investigated the distribution of age, gender and hunger-ratings between conditions and revealed that there were no differences in age between the active ( $M = 7.76$ ,  $SD = 1.63$ ) and control groups ( $M = 7.61$ ,  $SD = 1.73$ ,  $F_{1,139} = 0.27$ ,  $p = 0.606$ ). The groups were also well matched in terms of gender with the active group consisting of 53% female participants compared to 51% in the control group ( $\chi^2_1 = 0.026$ ,  $p = 0.872$ ). Similar levels of hunger were observed in the active ( $M = 5.14$ ,  $SD = 3.12$ ) and control groups ( $M = 5.31$ ,  $SD = 3.19$ ,  $F_{1,140} = 0.11$ ,  $p = 0.741$ ; see supplementary materials for a breakdown of sample characteristics for each experiment).

### 4.2. Learning effects

Reaction times on HF trials (HFRT), commission errors on UF trials (UFCE) and omission errors on HF trials (HFOE) across blocks were examined by way of mixed-measure ANOVAs. Food-category specific trials (as opposed to all go and no-go trials) were analyzed in order to allow comparisons between the active and control groups. This is because the active group participants were only required to respond on HF trials whilst the control group participants were required to respond on both HF and UF trials. As such, only HF go and UF no-go trials were analyzed as these are the trial types that both groups had in common. We expected the active group to show stronger learning and better performance overall than the control group due to the greater predictability of responses to the food stimuli (100% vs. 50% contingencies; Verbruggen & Logan, 2008).

Due to a computer error which resulted in the loss of HF and UF food label information, the reaction time and error data for specific food types was lost for 11 control participants. For the following learning data analyses therefore, a reduced control group sample size ( $n = 59$  compared to the original  $n = 70$ ) was used. The total sample size for learning effects analyses was 131 participants.

#### 4.2.1. Healthy food reaction time

Overall, participants became faster at responding to healthy foods as the experiment progressed (main effect of block:  $F_{3,387} = 3.74$ ,  $p = 0.011$ ,  $n^2_p = 0.028$ ; see Fig. 2). As expected, participants in the active condition also demonstrated significantly faster RTs ( $M = 731.16$ ,  $SE = 12.33$ ) than participants in the control condition ( $M = 780.82$ ,  $SE = 13.44$ ,  $F_{1,129} = 7.83$ ,  $p = 0.006$ ,  $n^2_p = 0.057$ ) and this was further qualified by a significant block by condition interaction ( $F_{3,387} = 3.46$ ,  $p = 0.017$ ,  $n^2_p = 0.026$ ), with active participants showing a faster learning rate than control participants who showed very little learning across blocks.

#### 4.2.2. Unhealthy food commission errors

As expected, participants in the active condition showed significantly lower commission errors on unhealthy food trials ( $M = 0.063$ ,  $SE = 0.01$ ) compared to the control group ( $M = 0.089$ ,  $SE = 0.01$ ,  $F_{1,129} = 4.86$ ,  $p = 0.029$ ,  $n^2_p = 0.036$ ). There were no other significant effects or interactions (for the effect of block and the interaction between block and condition, both  $F$  values  $< 0.889$  and  $p$  values  $> 0.443$ ).

<sup>2</sup> <http://hdl.handle.net/10871/27455>.



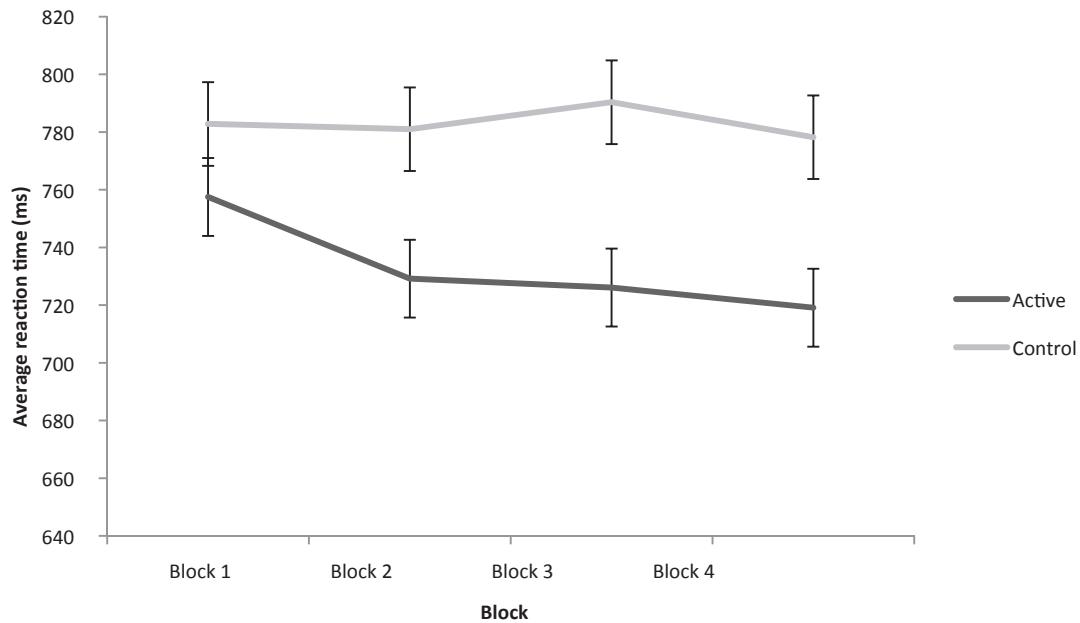


Fig. 2. Average reaction times with standard error on healthy food trials between the two groups.

#### 4.2.3. Healthy food omission errors

The rate of omission errors on healthy food trials was very low (overall  $M = 0.08$ ,  $SD = 0.07$ ). There were no significant effects of block or condition on omission errors on healthy food trials (for the main effects of block and condition and the interaction between the two,  $F$  values  $< 1.61$  and  $p$  values  $> 0.189$ ).

#### 4.3. Effects of training on food choice

The data were analyzed by means of a two-way between-groups ANOVA with condition and experiment as factors. Experiment was added as a between-subjects factor in order to investigate whether the specific experiment participants took part in affected the results (i.e., due to the small methodological and researcher differences). Number of HF cards chosen (out of the total of eight choices) was entered as the dependent variable. The number of UF cards chosen was the 'mirror' of the number of HF cards chosen (as these had to add up to eight) so only HF choices were examined.

The analysis revealed a significant main effect of condition on the number of healthy foods chosen ( $F_{1,136} = 5.03$ ,  $p = 0.026$ ,  $n^2_p = 0.036$ ), with participants in the active condition choosing significantly more healthy foods ( $M = 4.19$ ,  $SD = 2.21$ ) than participants in the control condition ( $M = 3.50$ ,  $SD = 1.78$ ). A significant main effect of experiment was also found ( $F_{2,136} = 7.89$ ,  $p = 0.001$ ,  $n^2_p = 0.104$ ). As this effect was unexpected, Bonferroni corrected pairwise comparisons were used to investigate the differences between experiments. These revealed that on average, participants in Experiment 2 chose a greater number of healthy foods ( $M = 4.76$ ,  $SE = 0.29$ ) than participants in both Experiment 1 ( $M = 3.24$ ,  $SE = 0.26$ ,  $p < 0.001$ ) and Experiment 3 ( $M = 3.74$ ,  $SE = 0.28$ ,  $p = 0.038$ ).

The interaction between condition and experiment approached significance ( $F_{2,136} = 2.94$ ,  $p = 0.056$ ,  $n^2_p = 0.041$ ) (see Table 1). To further investigate this, post-hoc t-tests were performed on each experiment separately and sensitivity analyses were conducted to determine the minimum detectable effect size for a two-tailed comparison of independent means with an alpha level of 0.015 (corrected for three comparisons) and power of 0.80. For Experiment 1, the minimum detectable effect size ( $d$ ) was 0.92, for

Table 1

Means and standard error (in brackets) for healthy food choices in each condition of each experiment.

Condition	Experiment		
	1	2	3
Active	3.67 (0.35)	5.57 (0.41)	3.58 (0.39)
Control	2.82 (0.36)	3.96 (0.40)	3.91 (0.41)

Experiment 2 it was 1.04 and for Experiment 3 it was 1.01. Therefore, these experiments were only powered to detect large effect sizes and so any conclusions drawn upon the basis of their individual results should be made tentatively. With a corrected critical  $p$  value of 0.015, the t-tests revealed a significant effect of training in Experiment 2 ( $t_{41} = 2.81$ ,  $p = 0.008$ ,  $d_z = 0.86$ ) but not in Experiment 1 ( $t_{52} = 1.60$ ,  $p = 0.117$ ,  $d_z = .43$ ) or Experiment 3 ( $t_{43} = -0.597$ ,  $p = 0.554$ ,  $d_z = 0.18$ ). Using the outcomes of these t-tests, Bayesian analyses were performed using the online calculator provided by the University of Missouri<sup>3</sup> (Rouder, Speckman, Sun, Morey, & Iverson, 2009) with scale  $r$  value set as default (0.707). This calculator produces a Bayes factor and a statement of whether or not the analysis supports the null hypothesis. Bayes factors were compared against the table provided in the paper by Wetzels et al. (2011). Where the calculator specifies that a Bayes factor supports the alternative hypothesis, the factor can be compared directly to the values in the table; where the factor is said to support the null hypothesis, the factor must be converted first (by dividing 1 by the calculated Bayes factor). Our Bayesian analyses revealed substantial evidence for the alternative hypothesis in Experiment 2 only ( $JZS B = 6.10$ ). Both Experiment 1 ( $JZS B = 1.28$ ) and Experiment 3 ( $JZS B = 2.93$ ) offered anecdotal support for the null hypothesis.

We conducted one further exploratory analysis to examine whether the age of participating children moderated the effects of training (i.e., due to increasing inhibitory control capacity throughout childhood; Williams, Ponsesse, Schachar, Logan, & Tannock, 1999; Best & Miller, 2010). An ANCOVA was performed

<sup>3</sup> <http://pcl.missouri.edu/bayesfactor>.

on the overall sample that included age (mean-centred) as a covariate, condition as the main predictor and number of healthy foods chosen as the outcome. The analysis revealed that whilst the effect of condition remained significant ( $F_{1,137} = 4.95, p = 0.028$ ), neither the main effect of age nor the age by condition interaction was significant (both  $p > 0.445$ ).

## 5. Discussion

A combined analysis of three very similar experiments in our first study suggests that food-related ICT has the potential to encourage healthier food choices amongst children when they are faced with a range of appetizing foods. Children who played an active version of the training (healthy foods = 100% go; unhealthy foods = 100% no-go) chose significantly more healthy foods (and therefore significantly fewer unhealthy foods) than children who played a control version of the training (both healthy and unhealthy foods = 50% go, 50% no-go). This dovetails with evidence that children consume significantly fewer calories from energy-dense foods after such training relative to non-food inhibition training (Folkvord et al., 2016) and mirrors results from studies conducted with adult participants (e.g., Veling et al., 2013). Furthermore, the effects of training were not moderated by age, suggesting that the training has similar effects across age groups in primary school children.

However, when analyses were run on each experiment individually, findings were less consistent. Experiment 2 demonstrated a highly significant effect of training whereas neither Experiment 1 nor Experiment 3 detected such an effect. Aside from the experiments being carried out by different student researchers, the principle methodological difference between Experiment 2 compared to Experiments 1 and 3 was the proportion of novel versus trained foods in the post-training shopping task. Specifically, the shopping task of Experiment 2 contained more trained foods (75% of total food cards) compared to the other two experiments (50% of total food cards). This could indicate that training effects may be stimulus specific, leading to an increase in healthy relative to unhealthy food selection only when response inhibition has been trained to the majority of energy-dense foods available. However, it is important to note that sensitivity analyses revealed that each experiment was only powered to detect strong effect sizes. As such, future research is required to test this hypothesis.

The experiments in Study 1 only compared post-training differences between groups, making it hard to draw conclusions about how the two training tasks influenced children's food choices. A potential issue is the possibility that the control task influenced food choices as well. For example, inconsistent mappings between food stimuli and go/no-go responses in the control task, coupled with exposure to energy-dense food stimuli, may lead to increased attention towards and intake/choice of these foods (Lawrence et al., 2015a). This concern is reinforced by the finding that participants in a similar inconsistent contingency control task consumed more (numerically) than participants who were trained to always respond to food stimuli (Houben & Jansen, 2011) and that this difference was significant when participants were low in inhibitory control (Houben, 2011). Alternatively, it is possible that the inconsistent contingencies between stimuli and responses in the control condition may have had an inhibitory effect on children's preference for energy-dense food. Children tend to show a preference for energy-dense foods over healthy foods (Birch, McPhee, Steinberg, & Sullivan, 1990; Johnson, McPhee, & Birch, 1991), which may elicit an approach bias to these foods (Saunders & Robinson, 2013). Additionally, associative learning is driven by prediction error (Rescorla & Wagner, 1972; Wasserman, Elek, Chatlosh, & Baker, 1993). It is therefore possible that if children have a pre-existing habitual "go"

response to energy-dense foods (e.g., due to repeated exposure and consumption cycles; Saunders & Robinson, 2013) then exposing them to trials upon which they must inhibit this response 50% of the time (as in the control condition) may lead to (albeit weak) inhibitory learning by reducing this stimulus-response contingency. A within-subjects analysis examining food choices both before and after training in both groups would be better able to detect the effects of training.

In Study 2, we therefore set out to investigate whether or not differences in food choice between groups measured at post-training can be explained by a change in the active group, control group, or both. To examine potential confounds associated with the control training condition, we also added a second control group who received inhibition training to non-food images (as in Veling et al., 2014; Lawrence et al., 2015b; Folkvord et al., 2016).

## 6. Study 2

The aim of Study 2 was to replicate the effect of training observed in the overall sample of Study 1 and investigate whether the control task used in Study 1 (henceforth referred to as the food control) differentially affected children's food choices compared to a non-food control task, as used in other studies (Folkvord et al., 2016; Lawrence et al., 2015b; Veling et al., 2014). Study 2 compared active training to both the non-food control task and the food control task in order to see if this latter task influences children's food choices. Based on the finding that training effects were (numerically) larger when the proportion of trained (versus novel) foods in the choice task was greater than half (i.e., in Experiment 2 of Study 1), the proportion of trained to untrained foods in the choice task for Study 2 was set to two-thirds.

We also employed a repeated-measures design that involved testing children's food choices at two time-points; at least five days before training and immediately after training. This enabled us to track any changes in food choice from pre- to post-training across the three groups and determine whether or not the results of inhibition training studies can be explained by changes in the active group or confounding effects of the control task.

An additional aim of Study 2 was to investigate the similarity between hypothetical measures of eating behavior (i.e., as measured in Study 1) and measures of eating behavior when faced with real foods (i.e., as in Folkvord et al., 2016). Whilst it has been found that both food images and real foods lead to similar neural and craving responses (Boswell & Kober, 2016), real food choices arguably constitute a more immediate reward which may affect behavior differentially (Appelhans, French, Pagoto, & Sherwood, 2016). Meanwhile, hypothetical measures of eating behavior are easier to implement and pose fewer ethical challenges as they do not involve giving children ad libitum access to energy-dense foods. However, in order to produce meaningful and applicable results, it is important to determine whether findings using hypothetical tasks can be extrapolated to situations involving real food items. As such, we provided children with both the hypothetical food choice task from Study 1 and a real food choice task in order to determine whether responses on each task were correlated and whether ICT had similar effects on both hypothetical and real food choices.

## 7. Method

### 7.1. Participants and design

Participants were 91 children aged 4–11 years ( $M = 7.53, SD = 2.11$ ; 47 male) recruited from four primary schools within the Exeter (Devon) and Thanet (Kent) areas. An a-priori power analysis was conducted (G-Power 3.1.9.2) based on data from Experiment 2,

Study 1. This analysis determined that a sample size of 53 would be sufficient to achieve statistical power of 0.80 for a study with three groups and one covariate (pre-training choice). However, a larger sample size was sought due to the possibility of attrition from baseline to test and due to uncertainty regarding the effect of training on the real food choice measure.

This study was of a one-way design with participants randomly assigned to one of three training conditions (active vs. food control vs. non-food control). The primary outcome measure (number of healthy food cards chosen) was taken at two time-points (pre- and post-training), with pre-training choice entered into between-group analyses of post-training choice as a covariate.

## 7.2. Materials and measures

### 7.2.1. Go/No-Go task

The Go/No-Go tasks used in Study 2 were similar to those used in Study 1 with the following alterations. All three tasks consisted of five blocks of 32 trials. The additional block was inserted as a practice block in order to standardize practice time and capture early learning data. The duration of each trial was fixed at 1500 ms, followed by an inter-trial interval of 1000 ms. At the end of each block, accuracy (number of correct responses) and average response time (in milliseconds) were presented as feedback.

As before, stimuli in each task were 16 images, with each image presented twice within each block. We used the go (happy emoticons) and no-go signals (sad emoticons) of Experiments 1 and 2 of Study 1. We chose to use these signals to maintain consistency with Experiment 2, which produced the strongest training effects. The food stimuli were altered slightly from Study 1 so that two images of each of eight snack categories (e.g., berries, sweets – see supplementary materials) made up the final 16 stimuli. These changes were made in order to allow the training to include the foods available in the real food choice task (detailed below). We used the same images in both food conditions of Study 2. As before, HF stimuli were consistently paired with go signals whilst UF stimuli were consistently paired with no-go signals in the active condition; in the food control condition, all images were paired equally often with go and no-go signals. Stimuli in the non-food control consisted of eight images of technological games equipment (e.g., head-phones, consoles) and eight images of sports equipment (e.g., balls, rackets). Sports stimuli were always paired with a go signal and technology stimuli were always paired with a no-go signal (Fig. 3). All stimuli were sourced from a food picture database (Blechert et al., 2014), internet search engines and the researcher's own photos.

Across all three conditions, the probability of a go signal

appearing on any given trial was equal to the probability of a no-go signal appearing. In both the active and non-food control conditions, the stimulus on a trial was entirely predictive of the response signal type whereas stimuli in the food control condition were non-predictive of any given signal.

### 7.2.2. Food choice shopping task (hypothetical choice)

The food choice task was similar to that used in Study 1, with the exception that 12 images were presented in total (instead of 16) and children were asked to select six foods (instead of eight). Furthermore, two different sets of cards were created so that participants chose from a different set at each time point (pre- and post-training). The order of presentation of these image sets was counterbalanced across participants. Images were sourced from a food picture database (Blechert et al., 2014), internet search engines and the researcher's own photos. Half of the 12 images in each set were HF images (e.g., apples, raspberries) and half were UF images (e.g., donuts, sweets; see supplementary materials). Eight of the cards in each set (two-thirds of total; four HF, four UF) were closely matched exemplars of foods shown in the food training tasks (e.g., apples, sweets) whilst four cards (two HF, two UF) represented novel foods that had not been shown in the food training. The eight cards that depicted trained foods were very closely matched to the foods shown in training (see supplementary materials) in order to encourage generalization at the item-level (e.g., apple) rather than the category-level (i.e., of healthy and unhealthy foods). This decision was made due to uncertainties regarding participants' categorization accuracy of different foods as healthy and unhealthy, which has been found to increase throughout childhood (Nguyen, 2007). The two card sets were also matched so that they depicted the same food categories but in a different form (e.g., green grapes in Set 1 vs. red grapes in Set 2; see supplementary materials). Images were chosen to represent portion sizes appropriate for children (e.g., one apple, a handful of grapes) and were depicted on a plain white background. As in Study 1, participants were instructed to choose foods that they wanted to eat as they would have the opportunity to consume some of these foods later in the experiment. This instruction was included to motivate children to make ecologically valid choices.

### 7.2.3. Hunger scale

The same 11-point Likert scale as used in Experiments 2 and 3 of Study 1 was used to measure hunger.

### 7.2.4. Real food choice task

Children were presented with six snack foods to choose from as a participation reward. Half of these were HF (strawberries, grapes,

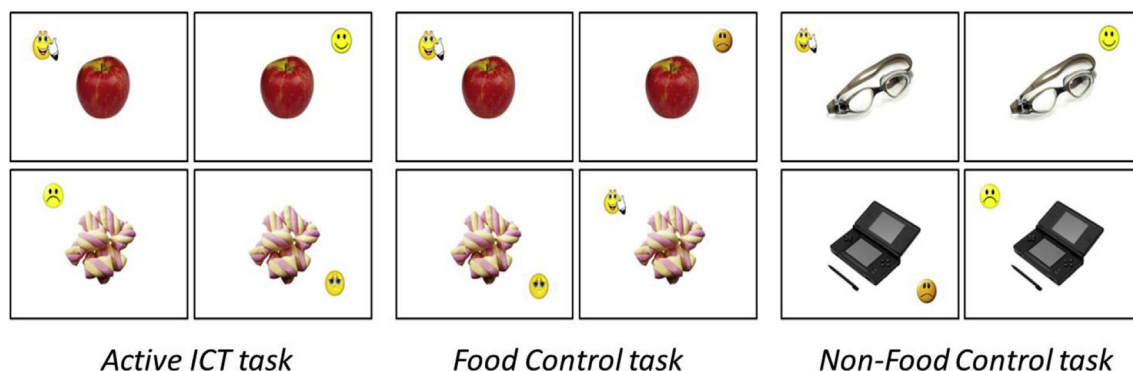


Fig. 3. Example screen shots from each training task.

carrots) and half were UF (chocolate buttons, marshmallows, cola-bottle sweets). All foods had appeared in both the active and the food control task and were presented in small Tupperware containers (capacity 250 ml) without any other packaging. Containers were all kept full to the brim with frequent replenishing between participants. Children were allowed to choose three items (e.g., one grape, one chocolate button, one strawberry).

### 7.3. Procedure

The experiment was split into two separate phases which were completed at least five days apart. Phase one (pre-training) was completed in small groups of up to ten participants at a time. Children were taken from the classroom to a separate area within the school (e.g., reading corner) and randomly allocated to a condition. Each participant was given an envelope containing the twelve cards for the hypothetical food choice task. Children were given alternating image sets (Set 1 or Set 2) in order to prevent them from copying the choices of the person sitting next to them. The children were then asked to remove their cards from the envelope and quickly place them facing upwards on the table in front of them. The timer was started and children were given one minute to choose six out of twelve foods. Afterwards, children were asked to complete the hunger scale before being returned to the classroom.

Children were tested individually in the second phase of the experiment (between five and ten days later). Children were taken from the classroom one by one and invited to play a game (the Go/No-Go training task). The game was explained to the children and they were told that they would get a practice round followed by four more rounds to try and beat their score. They were invited to start the game on the researcher's laptop whenever they were ready by pressing the space bar. At the end of each block, the experimenter congratulated the child on their score/reaction time and asked them if they wanted to try and beat that score in the next block. Immediately afterwards, the children were instructed to complete the hypothetical food choice task for the second time (using a different set of food images to that seen at pre-training). Children then filled in the hunger scale. It should be noted that the order of the hunger scale and the hypothetical food choice task was reversed between Study 1 and Study 2; this was done in order to ensure that training effects on hypothetical food choices (our primary outcome measure) were not diluted by asking children to focus on feelings of hunger.

Finally, children were offered a selection of foods as a participation reward (the real food choice task). Children were allowed to select three items from the food selection and could either consume them before returning to the classroom or choose to take them home in a small bag. We used a fixed order of choice tasks (i.e., hypothetical choice was always followed by real choice) in order to promote ecologically valid choices on the hypothetical choice task. This was because children were told during the hypothetical choice task that they would have the opportunity to consume some of their chosen foods at a later point in the experiment and as such, the choice of real foods necessarily followed this task. Another aim of this fixed order was to reinforce the cover story that this final task was a participation reward. After their selections had been made, children were debriefed in age appropriate terms.

## 8. Results

The complete SPSS data file is deposited in the University of Exeter's data repository, Open Research Exeter (ORE).<sup>2</sup>

### 8.1. Participants and preliminary analyses

A total of 91 children took part at both baseline and post-training. Exclusion criteria remained the same as Study 1 (average reaction times no greater than three standard deviations from group mean; minimum accuracy 60%) and no children were excluded on this basis. Due to a counterbalancing error, 10 children were shown the same food card set in the pre- and post-training shopping tasks. These children were excluded as they had not been able to follow the planned experimental procedure, leaving a total sample of 81 children (active  $n = 29$ , food control  $n = 25$ , non-food control  $n = 27$ ) aged 4–11 years ( $M = 7.54$ ,  $SD = 2.22$ ; 45 male).

Six children had dietary requirements that prevented them from taking part in the real food choice measure. A further six children were also unable to take part in this measure due to a food spillage on the final day of the experiment which restricted the choice of foods available. Therefore, a reduced total of 69 children were included in real food choice analyses (active  $n = 25$ ; food control  $n = 21$ ; non-food control  $n = 23$ ).

At pre-training, four children selected five or seven (instead of six) foods. Analyses were run both including these children (with pre-training HF card choice expressed as a proportion of total choices) and excluding them (with pre-training HF card choice expressed as a quantity). The interpretation of the results was not affected by their inclusion and so they have been included in the final analyses unless otherwise indicated.

Randomization checks revealed that the conditions were well matched for gender, age, pre-training hunger and pre-training HF card choices (expressed as a proportion of total choices; [Table 2](#)). With those participants who chose five or seven cards at pre-training excluded and pre-training HF card choice recorded as a quantity, the groups still did not differ significantly on this measure ( $F_{2,74} = 0.668$ ,  $p = 0.516$ ).

### 8.2. Task performance

Overall accuracy was high with the lowest average score at 69%. Mixed ANOVAs were used to investigate HFRT, HFOE and UFCE across the five blocks. The non-food control task did not contain food images and so sport image (go) trials were substituted for HF trials and technology images (no-go) trials were substituted for UF trials to allow a comparison of learning rates.

#### 8.2.1. Healthy food reaction time

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of block ( $\chi^2_9 = 53.95$ ,  $p < 0.001$ ) and so degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.71$ ). A significant main effect of block was found ( $F_{2,847,222.04} = 66.84$ ,  $p < 0.001$ ) with reaction times on HF (or sport) trials improving across blocks ([Fig. 4](#)). Training group also had a significant main effect ( $F_{2,78} = 5.20$ ,  $p = 0.008$ ), with those in the food control condition demonstrating significantly slower reaction times ( $M = 783.67$ ,  $SE = 23.83$ ) than both the active ( $M = 693.40$ ,  $SE = 22.12$ ,  $p = 0.007$ ) and the non-food control conditions ( $M = 689.14$ ,  $SE = 22.93$ ,  $p = 0.005$ ). The difference between the latter two groups was not significant ( $p = 0.894$ ). These main effects were qualified by a significant interaction between block and training group ( $F_{5,69,222.04} = 3.29$ ,  $p = 0.005$ ) which revealed a faster rate of learning in both the active and non-food control groups compared to the food control group ([Fig. 4](#)). This supports the idea that children learned the consistent stimulus-go associations in the former two tasks but not in the latter where stimulus-go associations were inconsistent and unpredictable ([Verbruggen & Logan, 2008](#)).



### 8.2.2. Healthy food omission errors

Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of block ( $\chi^2_9 = 100.11, p < 0.001$ ) and so degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ( $\epsilon = 0.58$ ). A significant main effect of block was found ( $F_{2.32,180.58} = 22.48, p < 0.001$ ) with omission errors on HF (or sport) trials reducing across blocks, regardless of condition. There were no other significant effects or interactions (for the effect of Condition and the interaction between Block and Condition, all F values  $< 0.48$  and all p values  $> 0.622$ ).

### 8.2.3. Unhealthy food commission errors

A significant main effect of block was found ( $F_{4,312} = 3.25, p = 0.013$ ) with commission errors on UF (or technology) trials reducing across blocks (Fig. 4). A significant main effect of condition was also found ( $F_{2,78} = 3.42, p = 0.038$ ) with the food control group ( $M = 0.107, SE = 0.014$ ) showing significantly more errors than either the active ( $M = 0.062, SE = 0.013, p = 0.022$ ) or the non-food control groups ( $M = 0.063, SE = 0.013, p = 0.029$ ). The difference between these latter two groups was not significant. This supports the idea that children learned the consistent stimulus-no-go associations in the latter two tasks but not in the former, where associations were inconsistent (Verbruggen & Logan, 2008). The interaction between block and training group was not significant ( $p = 0.842$ ).

### 8.3. Training effects on food choice

An ANCOVA was performed with number of HF cards chosen at post-training as the outcome variable, condition as a between-groups factor and pre-training HF card choice entered as a covariate. Pre-training HF card choice was entered as a proportion in

order to include the four participants who chose either five or seven (instead of six) foods in the pre-training choice task.

Pre-training HF choice had a significant main effect on post-training HF choice ( $F_{1,77} = 60.77, p < 0.001$ ). A significant main effect of condition was also found ( $F_{2,77} = 5.17, p = 0.008, \eta^2_p = 0.118$ ). Those in the active group chose significantly more HF cards (out of a possible six;  $M = 3.01, SE = 0.20$ ) than those in both the food control ( $M = 2.30, SE = 0.22, p = 0.012$ ) and the non-food control groups ( $M = 2.15, SE = 0.21, p = 0.005$ ). The difference between the two control groups was not significant ( $p = 0.784$ ).

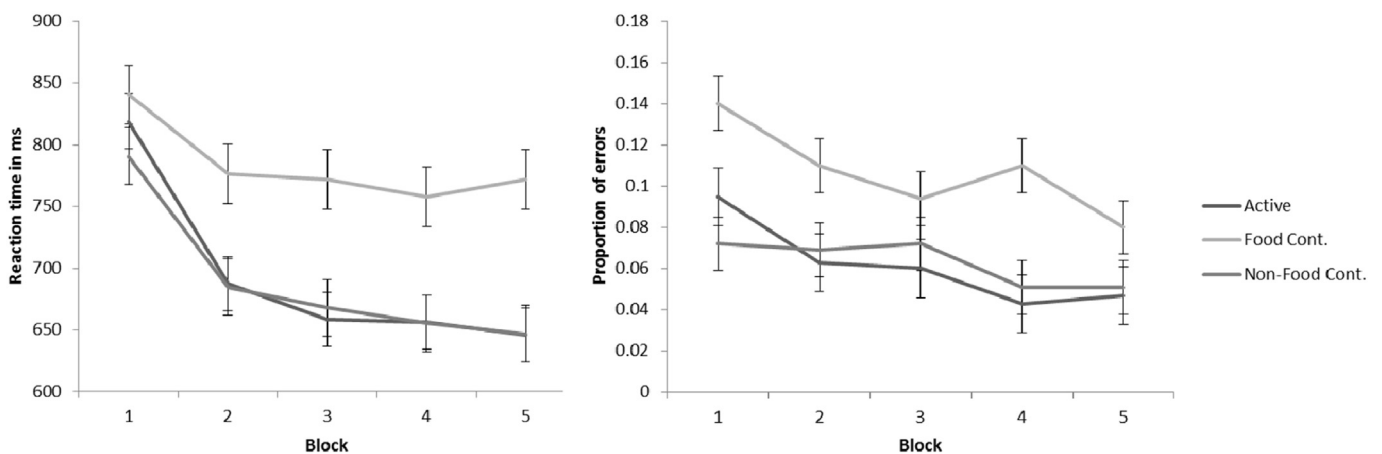
An additional analysis was run to explore whether the age of participating children moderated the effects of training. Age and the age by condition interaction were both added to the ANCOVA model (with the age variable being centred before analyses). This analysis revealed a significant main effect of condition ( $F_{2,74} = 5.35, p = 0.007$ ), pre-training healthy food choices ( $F_{1,74} = 62.85, p < 0.001$ ) and age ( $F_{1,74} = 5.77, p = 0.019$ ). However, the age by condition interaction was not statistically significant ( $p = 0.476$ ).

Means were calculated to examine the change in HF card choice (as a proportion of total choice) from pre-training to post-training. It was found that the active group increased the proportion of HF cards chosen from 0.36 to 0.52 ( $M_{\text{Change active}} = 0.161$ ) which is equal to a change of one additional HF card or a 44% increase in HF choice. By contrast, the two control groups displayed a negligible change in HF card choice as a proportion of total food choices ( $M_{\text{Change food control}} = 0.031; M_{\text{Change non-food control}} = 0.035$ ; Fig. 5), equal to a change of 0.19 and 0.21 cards respectively. Paired samples t-tests revealed that the change in proportion of HF cards chosen from pre-training to post-training was significant in the active group ( $t_{28} = -4.79, p < 0.001, \text{Cohen's } d_z = 0.89, \text{JSZ } B = 496.1$ ) but not in the food control ( $p = 0.477, d_z = 0.14, \text{JSZ } B = 3.74$ ) or the non-food control group ( $p = 0.353, d_z = 0.18, \text{JSZ } B = 3.27$ ).

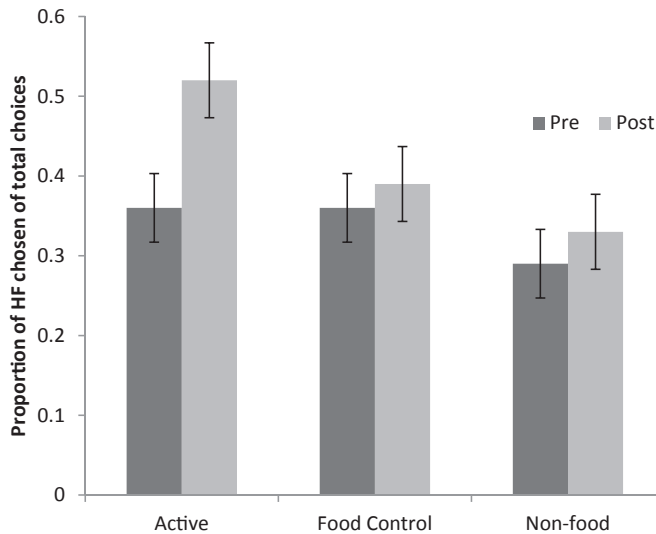
**Table 2**

A comparison of participant characteristics across groups. Data presented are means with standard deviations in brackets.

	Active Condition (n = 29)	Food Control (n = 25)	Non-Food Control (n = 27)	F/ $\chi^2$	p
Gender					
Male	13	15	17		
Female	16	10	10	$\chi^2_2 = 2.15$	0.341
Age	7.60 (2.29)	7.42 (2.29)	7.57 (2.17)	$F_{2,78} = 0.50$	0.951
Pre-training Hunger	6.90 (3.18)	5.80 (3.16)	7.19 (2.60)	$F_{2,78} = 1.54$	0.220
Pre-training Healthy Choices (Proportion)	0.36 (0.23)	0.36 (0.21)	0.29 (0.23)	$F_{2,78} = 0.70$	0.499



**Fig. 4.** Average healthy food reaction times and unhealthy food commission errors with standard error, between groups and across blocks.



**Fig. 5.** Average proportion of healthy food cards chosen (out of total cards chosen) with standard error at both pre- and post-training.

#### 8.4. Food choice measures: hypothetical vs. real

A correlation analysis was performed between post-training HF card choices and real HF choices in all children. The latter measure violated the assumption of normality due to a high number of children choosing no healthy foods at all. This was not resolved by transformations and therefore non-parametric Spearman's rho was calculated. The correlation revealed a highly significant and positive relationship between the two measures ( $r_s = 0.661$ ,  $p < 0.001$ ).

#### 8.5. Effects of training on real food choice

In order to determine whether or not real food choice was affected by training condition, a Kruskal-Wallis test was performed with condition as the grouping variable and real healthy food choice as the outcome variable. The effect of condition was significant ( $\chi^2_2 = 4.76$ ,  $p = 0.047$ ; one-sided test). Mann-Whitney tests were used to carry out planned comparisons to compare the groups. A significant difference was found between the active group and non-food control group only ( $U = 188.5$ ,  $p = 0.028$ ). There were no other significant comparisons between groups (for the comparisons between the active and food control and between the food control and the non-food control, all  $U$  values  $< 208.5$ ,  $p > 0.204$ ). The means showed that children in the active condition chose the greatest number of healthy foods ( $M = 1.00$ ,  $SD = 0.76$ ) followed by children in the food control ( $M = 0.71$ ,  $SD = 0.85$ ) and finally by the non-food control group ( $M = 0.52$ ,  $SD = 0.67$ ).

## 9. Discussion

Study 2 set out to investigate whether the effects of ICT on children's food choices are due to changes in the active condition or control condition. In particular, the study aimed to determine whether the food control task used in Study 1 (all foods = 50% go, 50% stop) constitutes a reliable baseline control. This was achieved by measuring hypothetical food choices both before and after participants completed one of three training tasks (active, food control or non-food control). Study 2 also set out to determine whether choices made with hypothetical food cards correlated with those made in a real food choice task in order to determine the validity of hypothetical choice tasks.

The analyses examining the change in healthy foods chosen in a hypothetical food choice task confirmed that the effects of ICT are due to changes in the active condition. Children in the active group chose a significantly greater number of healthy food cards (and therefore, significantly fewer unhealthy food cards) compared to children in both the food control group and the non-food control group whilst controlling for pre-training choices. The results of Study 1 were further replicated by the finding that age was not a significant moderator of these training effects. Furthermore, change data revealed that children were more likely to choose one extra healthy food (out of a possible six foods chosen) after active training whereas children in the two control groups did not show a significant change in the number of healthy choices made from pre- to post-training (note that children made their choices from a slightly different selection of foods at pre- and post-training).

Hypothetical choices and real food choices were highly correlated and training group significantly predicted real food choice. Children in the active group chose significantly more real healthy foods than those in the non-food (but not the food) control group. This finding suggests that the food control task may to some extent mask the effect of active training. Further research employing a more continuous variable such as calorie intake is required to determine whether or not tasks involving intermittent inhibition to rewarding food stimuli are appropriate to use as control tasks.

It is important to note that the real food choice task may have been less sensitive to detect training effects due to the very limited number of choices allowed (only three small items of food). The hypothetical task allowed children to select twice the number of foods. In addition, other studies investigating the effect of ICT on real eating behavior have examined effects on the quantities of energy-dense foods eaten and have observed reductions in calories consumed but not complete elimination of energy-dense food intake (e.g., [Folkvord et al., 2016](#)). Furthermore, unlike the hypothetical food choice measures, real food choice was only measured at one time point. The within-subjects design of the former measure is likely to have increased our ability to detect an effect of training on eating behavior in these earlier analyses. Nevertheless, our findings overall revealed that the three groups showed a similar pattern of post-training food choices regardless of the choice task used, suggesting that the hypothetical food choice task is a valid measure.

## 10. General discussion

Overall, the results of these studies suggest that food-related ICT is a promising tool for improving the eating behaviors of children. Children in the active condition chose significantly more healthy foods in a hypothetical food choice task than children in both a food control group (Studies 1 and 2) and a non-food control group (Study 2), and the effects of training were not influenced by children's age. This aligns with previous findings that, compared to control participants, such training reduces energy-dense food consumption and choice in both adults (e.g., [Lawrence et al., 2015b](#); [Veling et al., 2013](#)) and children ([Folkvord et al., 2016](#); [Jiang et al., 2016](#)). Furthermore, Study 2 contributes to the existing literature with the finding that from pre- to post-training, children chose on average one extra healthy food (swapping one unhealthy choice for a healthier alternative) in a hypothetical food choice game after active ICT but not after either control task. This is promising considering that children currently consume too few fruits and vegetables and too much sugar and fat ([Public Health England, 2014](#); [House of Commons Health Committee, 2015](#)). Other findings suggest that children are also likely to consume smaller portions of energy-dense foods after training ([Folkvord et al., 2016](#)). Together, these results highlight the potential of ICT as an applied

tool for improving health outcomes amongst children within the current nutritional climate.

A unique contribution of the current paper is the finding that both non-food and food control paradigms failed to result in any detectable change in hypothetical food choice from pre- to post-training. Tasks in which energy-dense foods are associated with inconsistent response inhibition (as in our food control task) have been used as both control (e.g., [Houben & Jansen, 2011](#)) and active tasks (e.g., [Forman et al., 2016](#)) although in the latter case, energy-dense food stimuli were the only stimuli paired with inhibition, meaning that the stimulus-response contingency was greater than zero. Nevertheless, no studies have previously investigated the effects of this control task on changing food choices from pre- to post-training in children or adults. Study 2 showed that hypothetical food choices did not change significantly from pre- to post-training in either control group, whilst a significant increase in healthy food choice was found for the active group. However, it must be noted that whilst the real food choices of the active group differed significantly from the non-food control group, they were not significantly different from the choices made in the food control group. Future research is needed to verify whether the food control group leads to significant changes in measures of real food consumption from pre- to post-training, both in children and adult populations.

One limitation of this study is the lack of follow up measures after training. Currently, little is known about the endurance of ICT effects and whether one session of training is sufficient for long-lasting changes or whether continued practice is required. One study with adults required participants to practice ICT four times within one week and observed reductions in weight up to six months later ([Lawrence et al., 2015b](#)), although individuals in this study may have been motivated to change their eating habits and lose weight. In order for ICT to be applied as a dietary change intervention for children, it is imperative that the long-term effects of training are investigated.

A further limitation of the current study is the lack of baseline BMI and impulse control measures in the sample. Previous research with adults has found that ICT tends to work best with those who are more impulsive at baseline ([Houben, 2011](#)). It would be interesting to see whether this effect replicates in children or whether ICT affects the eating behavior of all children due to their generally lower and underdeveloped inhibitory control ([Bunge et al., 2002](#)). Furthermore, it would be important to understand whether or not ICT can help overweight and obese children to change their dietary choices and manage a healthier weight. The finding that ICT tends to work best in adults with a higher BMI and a greater motivation to consume energy-dense foods ([Veling et al., 2013, 2014](#)) suggests that effects may be stronger in more overweight children; however this hypothesis must be tested before ICT is offered as a clinical intervention.

Efforts should also be made to explore the effects of training on more ecologically valid measures of eating behavior and diet change. Whilst the principle aim of including the real food choice task was to explore whether choices made using hypothetical choice tasks reflected those that would be made in the face of real foods, it is debatable whether offering participants three small items of food constitutes a real-life measure of food choice. Portion size is an important contributor to obesity (e.g., [Fisher, Liu, Birch, & Rolls, 2007](#)) and should be examined by using outcome measures that allow children greater freedom in the selection and self-serving of a range of foods. Finally, it is worth noting that the hunger scale used in these experiments may be confusing for some children. In the current studies, the researchers made every effort to ensure that this measure was thoroughly explained to participants, however it is possible that without this guidance, the

presence of happy and sad faces along the scale may lead some children to report a score based on their mood, rather than their hunger. Researchers who wish to measure children's hunger should take this into account and explore other child-friendly scales (i.e., that provided by [Bennett & Blissett, 2014](#)).

Future research should seek to address these issues whilst endeavoring to deepen current understanding of training mechanisms. For example, research with adult participants has indicated that inhibiting motor responses to energy-dense foods leads to devaluation of such stimuli ([Chen et al., 2016; Veling et al., 2008](#)) and could also lead to the development of automatic stimulus-response associations between No-Go foods and stopping ([Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017](#)). These mechanisms were not examined here due to the time constraints of testing within schools and have not yet been investigated in children but they would provide a fruitful avenue for future research. Furthermore, it is unknown whether or not the emotive Go and No-Go signals used in the current studies strengthened training effects. Given that research suggests that the pairing of energy-dense foods with motor inhibition ([Chen et al., 2016; Veling et al., 2008](#)) or negative images ([Hollands et al., 2011; Veling et al., 2011](#)) affects food evaluations and choice, it would be interesting to see whether combining the two approaches has an additive influence on food choice.

To conclude, these studies indicate that ICT could be used as a tool to encourage the choice of healthy foods such as fruit and vegetables over energy-dense snacks. Furthermore, our results suggest that the previously observed effects of ICT are due to positive dietary changes in the active training group rather than an artefact of the control task used. Further work is required to determine whether the current findings extend to real life food choices and to everyday contexts. Nevertheless, this study supports the potential of ICT as a future health intervention that, unlike current educational campaigns, bypasses the need for a detailed understanding of dietary guidelines, a strong motivation to change and effortful self-control. It would be interesting to combine food ICT with education and other techniques such as behavioral inhibition towards real foods in a game ([Jiang et al., 2016](#)) or during food exposure and response prevention ([Boutelle & Bouton, 2015; Jansen, Schyns, Bongers, & van den Akker, 2016](#)) to see whether effects of training could be further strengthened. These combined approaches could contribute towards redressing the current unhealthy imbalance in children's dietary intake and help to reduce childhood obesity.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.appet.2017.05.010>.

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