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37

Introduction

38 The food we eat has a direct impact on our health (Afshin et al., 2019). A high intake of non-milk
39 extrinsic sugars is associated with a high energy intake, and with long-term conditions such as obesity
40 (Dong, Bilger, van Dam, & Finkelstein, 2015; Malik, Pan, Willett, & Hu, 2013; Public Health England,
41 2015; SACN, 2015), Type 2 diabetes (Hu, 2013; Malik et al., 2010) and poor dental health (Meier et al.,
42 2017; Sheiham & James, 2015). However, 98% of children in the UK consume more non-milk extrinsic
43 sugar than the recommended limit (Public Health England, 2018) while only 18% meet the
44 recommended five portions of fruit and vegetables per day (NHS Digital Lifestyles Team, 2019).

45 Given that the majority of children's sugar intake comes from non-core foods such as soft
46 drinks, biscuits, cakes and puddings (Public Health England, 2015), replacing these sugary snacks with
47 a piece of fruit could help to redress the existing dietary imbalance. However, early preferences for
48 sweet versus bitter flavours mean that children prefer energy-dense foods over fruit and vegetables
49 (Birch & Fisher, 1998), with flavour often being the primary driver of children's food choices (Nguyen,
50 Girgis, & Robinson, 2015). Younger children in particular are less likely to choose healthier foods over
51 more palatable, energy-dense options (Ha et al., 2016). Energy-dense foods are often easily
52 accessible, convenient, and highly visible (e.g., through marketing) (Swinburn et al., 2011), and
53 children are especially susceptible to the influence of food marketing (Boyland et al., 2016). Some
54 strategies to encourage fruit and vegetable intake can also result in unintended negative
55 consequences; for example telling children that healthy foods have instrumental value (e.g., carrots
56 help you to see in the dark) can actually decrease perceptions of tastiness and the likelihood of
57 subsequent intake (Maimaran & Fishbach, 2014).

58 Many interventions to improve the nutritional quality of children's diets are not successful,
59 whilst those that are tend to be resource-intensive, multi-component interventions (Bourke,
60 Whittaker, & Verma, 2014; Hendrie, Lease, Bowen, Baird, & Cox, 2017; Hodder, O'Brien, Tzelepis,
61 Wyse, & Wolfenden, 2020; Johnson, Zarnowiecki, Hendrie, Mauch, & Golley, 2018; Knai, Pomerleau,
62 Lock, & McKee, 2006), which may not be feasible to implement in all settings or with limited budgets
63 (Ward et al., 2017). Digital behaviour change interventions (DBCI) can reduce the costs associated
64 with delivering interventions (e.g., time, personnel, financial), and facilitate accessibility where
65 attending in-person services is difficult or expensive (Hayes, Eichen, Barch, & Wilfley, 2017; Murray,
66 Burns, See, Lai, & Nazareth, 2005; Price et al., 2014; Sallinen, Schaffer, & Woolford, 2013; Sorgente et
67 al., 2017). DBCIs are also a prime platform for delivering content in a gamified way that appeals to
68 children (Chow et al., 2020).

69 Food-specific inhibition training (FSIT) is an example of a DBCI that aims to gamify the learning
70 of healthier eating habits. Users make motor responses (e.g., key presses or touchscreen taps) in
71 response to stimuli presented on screen (typically healthy foods or neutral images), but refrain when
72 energy-dense foods such as chocolate, sweets and crisps are presented (Houben & Jansen, 2011;
73 Lawrence et al., 2015). The effect of this simple task is to reduce calorie intake and choice of energy-
74 dense foods, both amongst adults (Aulbach, Knittle, & Haukkala, 2019; Jones et al., 2016) and children
75 (Folkvord, Veling, & Hoeken, 2016; Porter et al., 2018).

76 FSIT is an example of an intervention that targets 'automatic' drivers of eating behaviour.
77 Many health behaviour change interventions focus on education, and do not account for the
78 influence of these 'automatic' drivers of behaviour (Johnson et al., 2018; Marteau, Hollands, &

79 Fletcher, 2012). However, these processes are crucial for eating behaviour; automatic reward
80 responses to food predict craving and food intake (Boswell & Kober, 2016; Lawrence, Hinton,
81 Parkinson, & Lawrence, 2012), particularly when inhibitory control is low, as is likely the case for
82 children given that neural substrates associated with self-control are not mature until early adulthood
83 (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Keller & Bruce, 2018). It was originally
84 thought that FSIT impacted eating behaviour by strengthening response inhibition in the face of
85 tempting stimuli, however research with adult participants has found that FSIT effects are more likely
86 to be driven by reductions in the reward appeal (devaluation) of foods paired with response inhibition
87 (Veling, Lawrence, Chen, Van Koningsbruggen, & Holland, 2017).

88 Devaluation of food stimuli also occurs after evaluative conditioning, whereby food stimuli
89 are repeatedly paired with images that evoke some kind of emotive or evaluative response (e.g.,
90 positive and negative facial expressions), subsequently impacting liking and choice of those items
91 (Hensels & Baines, 2016; Shaw et al., 2016). While it could be argued that FSIT may be a form of
92 evaluative conditioning (i.e., the No-Go cue or the act of not responding could serve as a negative
93 stimulus, leading to devaluation after repeated pairing with certain food stimuli), research has found
94 that devaluation after FSIT results from response inhibition itself rather than evaluative conditioning
95 (Chen, Veling, Dijksterhuis, & Holland, 2016).

96 If both FSIT and evaluative conditioning can lead to devaluation of foods and subsequent
97 behaviour change via different mechanisms, combining them into one task could have a cumulative
98 impact on food choices. Our past research with children used a version of FSIT containing happy and
99 sad emoji faces as the Go and No-Go signals respectively (Porter et al., 2018) meaning that this
100 'emotive-FSIT' version of the task arguably also contained an evaluative conditioning element. Whilst
101 FSIT can also significantly impact children's calorie intake when neutral response signals such as
102 different shapes are used (Folkvord et al., 2016), it is unknown whether emotive signals can augment
103 FSIT effects. This question is of particular interest given that our team has developed a free FSIT app
104 ('FoodT'¹) for iOS and Android devices which uses neutral response signals (green and red circles).
105 This app was developed based on FSIT validated in adults (e.g., Lawrence et al., 2015; Lawrence, Van
106 Beurden, Javaid, & Mostazir, 2018) and has not yet been tested with children. If emotive signals are
107 found to be more impactful for child samples, such amendments could be easily implemented into
108 future FSIT paradigms. To explore this, we ran a series of studies to investigate whether this ready-to-
109 use FSIT app (which uses neutral response signals) and the computer-based FSIT used in earlier
110 research (which uses emotive signals) yielded meaningfully different results in FSIT effects on
111 children's food choices.

112 **Study 1**

113 Our first study tested whether combining FSIT and evaluative conditioning could enhance healthy-
114 food choice versus standard FSIT.. In this study, we used the same emotive-signal, computer-based
115 task as in Porter et al., 2018 and developed a near-identical version (still computer-based) using
116 neutral signals².

¹ <http://www.exeter.ac.uk/foodt>

² For pragmatic reasons associated with access to university laptops with EPrime software, a further (harder) variant of the task was developed using an online server and tested simultaneously in a separate sample of

117 An additional aim of Study 1 was to determine whether FSIT effects endure beyond the
118 period immediately post-training. Previous work has tested children's eating behaviour within a single
119 experimental session (Folkvord et al., 2016; Porter et al., 2018), whereas research with adults has
120 found evidence of lasting effects of repeated FSIT sessions (e.g., four or more in a single week) on
121 outcomes over a number of months (Lawrence et al., 2015). In this study, we set out to investigate
122 whether any FSIT effects on food choices would still be present one week later and whether these
123 could be augmented or reinstated with a second FSIT "top-up" session.

124 Our primary research question was whether combining FSIT with evaluative conditioning (by
125 using emotive response signals) leads to larger training effects (versus control) compared to FSIT
126 using neutral signals. We hypothesised that children who completed FSIT (emotive or neutral) would
127 choose a greater number of healthy foods in a time-limited, hypothetical choice task than children
128 who completed a control task. Secondary questions included whether FSIT effects on food choice
129 would endure one week later, and whether a second top-up FSIT session would augment/reinstate
130 any training effects one week later. Ethical approval for this study was granted by the University of
131 Exeter CLES Psychology Ethics Committee (reference 2017/1638).

132 **Materials and Methods**

133 **Participants and Design**

134 Participants for this study were children at two schools in the Exeter and East Devon (UK)
135 areas, whose parents returned the participation consent form. School A was located in a ward where
136 94.7% of residents are White, 2.8% Asian, 0.4% Black, and the remainder of Mixed or Other ethnic
137 groups. In 2020, the proportion of children eligible for free school meals (FSM) was 9.6% (national
138 average 17.3%; ONS, 2020). School B was located in a ward where 98.8% of residents were White,
139 0.3% Asian, 0.1% Black, and the remainder of Mixed or Other ethnic groups. In 2020, the proportion
140 of children eligible for FSM was 1.6% (school information collected via national and local government
141 websites³).

142 Power calculations were conducted using G*Power 3.1 to find the required sample size to
143 detect an effect size (f) of 0.3587 (taken from Study 2 of Porter et al., 2018) at 80% power for a study
144 design with three conditions, three measurement points, and with an alpha level of 0.05. This yielded
145 a calculated sample size of 54 participants. A recruitment target of 90 participants (30 per condition)
146 was set to insure against attrition over study sessions.

147 The study was of a mixed design, with a between-subjects factor with three levels (condition:
148 FSIT-Emotive vs. FSIT-Neutral vs. Control) and a repeated measures element, with outcomes
149 measured at three time points (immediately post-training in session 1, at the start of session 2, and
150 immediately post-training in session 2).

151 **Measures and Materials**

children. The results regarding this variant are not reported here but will appear in the lead author's upcoming thesis

³ Resources consulted = <https://get-information-schools.service.gov.uk/> and <https://www.devon.gov.uk/factsandfigures>

152 **Go/No-Go Training Task.** This task was programmed using EPrime software and accessed on
153 university-owned laptop computers. Stimuli appeared on the screen one at a time for 1250ms,
154 followed by a 1250ms inter-trial interval. Participants were required to press the spacebar when the
155 stimulus was accompanied by a Go-signal but not when the stimulus was paired with a No-Go-signal.
156 In Session 1, the tasks consisted of five blocks of 32 stimuli, while in Session 2, a top-up session of
157 three blocks was used. Accuracy (presented as correct trials out of 32) and reaction time (RT;
158 presented as average response time in milliseconds) feedback was presented to participants after
159 each block

160 Active FSIT stimuli were 16 food images identical to those used in earlier research (Study 2,
161 Porter et al., 2018; eight healthy such as apples, blueberries etc., and, eight energy-dense such as
162 chocolate, crisps) while Control-task stimuli were sixteen games-equipment images (eight sports,
163 eight technology). Stimuli were presented twice per block. In the FSIT-Emotive task, Go-signals were
164 happy-face emojis and No-Go-signals were sad-face emojis. In the FSIT-Neutral and Control tasks, Go-
165 signals were green "Go" signs and No-Go-signals were red "Stop" signs. Each stimulus was presented
166 with two variants of the relevant signal type to encourage stimulus-response learning over stimulus-
167 signal learning (Best, Lawrence, Logan, McLaren, & Verbruggen, 2016; Bowditch, Verbruggen, &
168 McLaren, 2016). There were three variations of each signal type (i.e., three of each of Emotive-Go,
169 Emotive-No-Go, Neutral-Go, Neutral-No-Go).

170 **Hypothetical Food Choice Task.** Food choices were measured immediately after training in
171 Session 1, at the start of Session 2, and immediately after training in Session 2. This task was hosted
172 on a university server and accessed via the web browser. Sixteen food images (eight healthy, eight
173 energy-dense) were presented on the screen in a grid. Six of the healthy food images and six of the
174 energy-dense food images were different images of the same food types that appeared in the active
175 FSIT tasks (e.g., apple, chocolate bar), with the rest being novel foods that did not appear in the FSIT
176 tasks. Some images were those used by Porter et al., (2018), some were taken from the internet, and
177 some were photographed by the first author. Each image presented approximately one portion of
178 that food. Three image sets were created so that different images could be shown at each of the
179 three measurement points. The order in which these three image sets were presented was
180 counterbalanced across participants.

181 Children clicked on the eight foods they wanted most within a 60-second time limit. A time
182 limit was imposed based on findings that FSIT effects disappear when longer time-periods are allowed
183 for deliberation (Veling, Chen et al., 2017). If children did not select eight foods within the time limit,
184 the researcher offered them a second attempt. The number of healthy-foods chosen was recorded as
185 the outcome variable (as children were only allowed to choose eight foods, this was directly
186 proportional to the number of energy-dense foods chosen). Children were asked to pretend that
187 these were real foods that they could eat, to motivate ecologically valid choices⁴. Children were able
188 to modify their choices as many times as they wanted to within the time limit.

⁴ This differs from the procedure in Porter et al., (2018) where children were told that they would be given one of their choices upon study completion to motivate ecologically valid choices. This was not possible in the current study due to group-testing, and the subsequent logistical issues involved in transporting required amounts of equipment and food via public transport.

189 Procedure

190 Letters were sent to parents, containing a brief description of the study and a consent form to
191 return to school. Only children whose parents consented were invited to participate. Children took
192 part in groups of 4-15 at a time. Group sizes were dependent on the requirements of the schools.
193 Groups were mixed with regards to FSIT condition.

194 For session 1, groups of children were taken from the classroom to an activity area where the
195 laptops were set up. Instruction sheets showed the specific response signals children should attend to
196 (i.e., happy/sad faces or Go/Stop signs) and the experimenter delivered verbal instructions to aid
197 understanding. Once children had been instructed to begin, the experimenter observed children's
198 performance to ensure they understood the task and provided additional instructions and support for
199 children who were struggling with the task. As each child reached the end of the Go/No-Go task, the
200 experimenter opened the instruction page for the first food choice task (Food Choice 1) for each child
201 and asked them to wait at the instruction screen (no foods visible) until their classmates were ready
202 to begin the food choice task. Again, the experimenter delivered verbal instructions to accompany
203 those present on the screen, emphasising the time limit and that they should pretend that they were
204 choosing real foods to eat.

205 After a week-long interval, Session 2 began with a food choice task (Food Choice 2a) followed
206 by a "top-up" of the same Go/No-Go training task as before, and then a final food choice task (Food
207 Choice 2b). Before each task, children were given brief verbal instructions to refresh their memory.

208 Data Preparation and Analysis

209 Planned exclusion criteria included overall accuracy on the Go/No-Go task below 60%, No-Go
210 accuracy below 50%, and average reaction times (RTs) beyond three standard deviations of the mean
211 for that condition. Additional exclusions were made when data from the Go/No-Go tasks were lost
212 due to technical errors, researcher errors caused a deviation from the planned procedure (these
213 included instances where children were accidentally shown the wrong food choice image set and
214 were not fully counterbalanced, and where children were given the wrong task in the second session)
215 and for child absence on testing days, or requests to drop-out.

216 Repeated measures ANOVAs investigated the effect of Condition on Go trial RTs, Go trial
217 omission errors and No-Go trial commission errors across blocks. Models were analysed separately
218 for each session. Where Mauchly's test for sphericity was significant, corrections were used
219 (Greenhouse-Geisser when $\epsilon < .75$, Huynh-Feldt otherwise). All pairwise comparisons were
220 Bonferroni corrected.

221 An ANOVA was used to investigate the effect of Condition on the number of healthy-foods
222 chosen in Food Choice 1. This analysis was one-tailed as it was a direct replication of the analyses
223 conducted by Porter et al., (2018). Unadjusted planned comparisons between each FSIT group versus
224 the Control group were conducted (replicating earlier findings, as before). Bayes factors for these two
225 planned comparisons were calculated using an online calculator (Dienes, 2014). For each comparison,
226 the inputs to this calculator consisted of the mean difference between conditions, the standard error
227 of this difference, and a prior based on all previous studies conducted by our research group and
228 calculated using another calculator provided by Dienes and colleagues (prior = 0.8569); both the

229 Bayes factor calculator and the prior calculator can be found online⁵. A repeated measures ANOVA
 230 investigated healthy-food choices across the three measurement-points. The full dataset is available
 231 at <https://osf.io/wkh5j/>.

232 Results

233 Preliminary Analyses

234 Before exclusions, 112 children (59 female) aged 5-10 years ($M = 7.93$, $SD = 1.84$; age and
 235 gender information were missing for two children) were enrolled. Eight children were excluded from
 236 session 1 (absence on experiment days = 5, drop-out = 2, data loss = 1), with no further exclusions
 237 made on the basis of poor Go/No-Go task performance, resulting in a sample of 104 children (57
 238 female) aged 5-10 years ($M = 7.93$, $SD = 1.83$). A further eleven children were excluded from session 2
 239 (absence on experiment days = 6, experimenter error = 3, low Go/No-Go task accuracy = 2), resulting
 240 in a sample of 93 children (52 female) aged 5-10 years ($M = 7.73$, $SD = 1.81$) for these analyses. The
 241 minimum target sample size of 30 per condition was met in both sessions (see Table 1 below).

242 *Table 1: Sample characteristics for each condition at each session*

	FSIT-emotive	FSIT-neutral	Control
Session 1 - n	34	35	35
Age – M (SD)	8.04 (1.88)	7.96 (1.81)	7.79 (1.86)
Gender - % female	52.9%	60.0%	51.4%
Session 2 - n	30	32	32
Age – M (SD)	7.82 (1.88)	7.78 (1.79)	7.60 (1.83)
Gender - % female	53.3%	62.5%	51.6%

243

244 One participant had missing data for Go RTs in the first block of Session 1 due to not making
 245 any correct Go responses in this block (the participant completed the task with 100% Go accuracy for
 246 the remaining blocks, meaning that they passed the accuracy inclusion criteria). This missing value
 247 was filled in with the mean for the participant's age group and condition at Block 1, Session 1.

248 Go/No-Go Task Performance Analyses

249 In Session 1, RTs got significantly faster across blocks ($F_{3,538, 357.341} = 27.98$, $p < .001$, $n^2_p = .217$;
 250 Huynh-Feldt corrected; Figure 1), with no significant differences between conditions ($p = .297$). In
 251 Session 2, the Block x Condition interaction was significant ($F_{4,180} = 3.64$, $p = .007$, $n^2_p = .075$; Figure 1),
 252 with RTs getting faster over time in the Active-Emotive group ($F_{2,89} = 3.51$, $p = .034$, $n^2_p = .073$), getting
 253 slower in the Control group ($F_{2,89} = 4.30$, $p = .017$, $n^2_p = .088$) and remaining stable in the Active-
 254 Neutral group ($p = .146$).

255 Commission error rates improved significantly across blocks in Session 1 ($F_{3,231,326.328} = 4.48$, p
 256 $= .003$, $n^2_p = .042$; Huynh-Feldt corrected). Unexpectedly, there was a main effect of Condition ($F_{2,101} =$
 257 5.67 , $p = .005$, $n^2_p = .101$) with the FSIT-Emotive group showing significantly higher error rates ($M =$
 258 $.109$, $SE = .012$) compared to the FSIT-Neutral ($M = .064$, $SE = .011$, $p = .019$) and Control groups ($M =$
 259 $.060$, $SE = .011$, $p = .009$; Figure 1). In Session 2, commission error rates varied significantly across

⁵ http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm

260 blocks ($F_{2,180} = 3.93, p = .021, n^2_p = .042$). There was a significant effect of Condition ($F_{2,90} = 3.10, p =$
 261 $.050, n^2_p = .064$) however no pairwise-comparisons were significant.

262 *Figure 1: Mean and standard error per block for Go trial Reaction Times and proportion of No-Go trial*
 263 *commission errors for each condition across blocks*

264 *[INSERT FIGURE 1 HERE]*

265 *Note: lower RTs/error rates indicate better performance*

266 Food Choices

267 The main effect of Condition was not significant, and healthy-food choices did not
 268 significantly differ between children in the FSIT-Emotive ($M = 3.77, SE = 0.35$), FSIT-Neutral ($M = 3.91,$
 269 $SE = 0.36$) and Control groups ($M = 3.27, SE = 0.36$) at Food Choice 1 (immediately after the first
 270 training; all p values $> .210$). Bayes factors for the pairwise-comparisons sat between 1/3 and 3 (FSIT-
 271 Emotive BF = 1.15, FSIT-Neutral BF = 1.80), meaning that the evidence was not sufficiently conclusive
 272 to support either the null or alternative hypothesis.

273 Healthy-food choices decreased significantly over time ($F_{1,702,144.639} = 3.29, p = .048, n^2_p = .037$;
 274 HF corrected; Linear Contrast $F_{1,85} = 4.42, p = .038$; see Figure 2). Neither the effect of Condition nor
 275 the Time x Condition interaction was significant. Missing values were deleted listwise, meaning that
 276 different mean values for Food Choice 1 are presented in Figure 2 compared to those reported above,
 277 due to session 2 exclusions.

278 *Figure 2: Mean number of healthy-foods chosen at each time-point for each Condition, with standard*
 279 *error.*

280 *[INSERT FIGURE 2 HERE]*

281 *Note: Food Choice 1 occurred immediately after training in Session 1, 2a occurred one week later*
 282 *before the top-up training and 2b occurred immediately after the top-up training.*

283

Discussion

284 This study aimed to investigate whether combining evaluative conditioning and FSIT would encourage
 285 healthier choices among children compared to standard FSIT alone. We compared a task that used
 286 happy and sad faces as Go and No-Go signals respectively (FSIT-Emotive condition) and a task that
 287 used neutral (green Go and red No-Go) signals (FSIT-Neutral condition) against a non-food Control
 288 task, measuring children's food choices in a time-limited, hypothetical choice task at three time
 289 points. Our hypothesis of higher healthy-food choice in the FSIT tasks versus Control was not
 290 confirmed; unexpectedly, we failed to replicate the significant training effects previously observed
 291 (Porter et al., 2018), despite the FSIT-Emotive task being identical to that used in the earlier research.
 292 Instead, there were no significant differences between groups at any time-point, and healthy-food
 293 choices decreased significantly over time with no evidence of this trend differing between groups.

294 Due to the non-significant results of this study, we were unable to determine whether
 295 evaluative conditioning can enhance FSIT effects on food choices. There are a number of differences
 296 between this study and the earlier study by Porter and colleagues (2018) that could help to explain

3297 the discrepancy in results. Firstly, in the earlier study, children were told that they would receive one
3298 of their food choices at the end of the day, to motivate ecologically valid choices. This was not
3299 possible in the present study for practical reasons. Children were encouraged to imagine that these
3300 were real foods that they would eat, but this may not have been enough, and future studies should
3301 aim to use real food outcomes to ensure ecological validity.

3302 In addition, the food choice tasks in the present study were timed by the computer and
3303 although children were not alerted to this feature, they were able to modify their choices as many
3304 times as they wanted to within the 60-second window. Comparatively, the earlier study involved
3305 researchers working one-on-one with children for this task, meaning that children could be prevented
3306 from changing their choices or deliberating for too long. Past research with a similar response training
3307 task has found that effects on food choices are eliminated when adult participants are offered a
3308 longer time period to make their choices (Veling, Chen, et al., 2017). These results could indicate that
3309 a similar effect occurs with children. Future studies should explore whether FSIT effects on food
3310 choices are impacted by the amount of time permitted for food choices.

3311 Alternatively, it could be that the group-testing environment in this study impacted children's
3312 attention and engagement with the FSIT task (e.g., due to distraction by other children). The FSIT-
3313 Emotive task had a significantly higher no-go commission error rate than the other two tasks, with a
3314 mean of 0.109. In comparison, the commission error rate for the FSIT-Emotive task was 0.063 in the
3315 earlier study (in which children were tested individually, or in smaller groups of a maximum of four
3316 with two researchers present). A meta-analysis of studies with adult participants found that accuracy
3317 on inhibition trials is a crucial predictor of training effects on outcomes (Jones et al., 2016). Therefore,
3318 poorer task performance in the current study may have minimised training effects and resulted in the
3319 non-significant effects observed here. The poorer no-go performance may have impacted the FSIT-
3320 emotive task more than the other tasks due to the higher similarity between Go and No-Go signals
3321 (i.e., yellow circles that differed by variations in facial expression, compared to potentially more
3322 easily-discriminable green and red signs). Future studies should ensure that the conditions during FSIT
3323 allow children to concentrate and engage with the task.

3324 Study 2

3325 In Study 2, we implemented the methodological recommendations of Study 1 (i.e., using real food
3326 rewards to improve ecological validity of outcome measures; implementing FSIT individually in a
3327 quieter, less distracting environment) to compare the FSIT-emotive task against the neutral FSIT task
3328 included in the FoodT app. These methodological changes brought the method of Study 2 more
3329 closely in line with the methods used in Porter et al., (2018). Children worked with the experimenter
3330 one-on-one to create a more controlled testing environment, and when taking part in the time-
3331 limited hypothetical food choice task, children were told that they would receive one of their choices
3332 at the end of the study. Real food choices were also measured. Thirdly, a baseline measure of
3333 hypothetical food choices was taken to help understand (i) whether groups were well matched in
3334 their healthy-food choices at the outset, and (ii) whether any changes occurred within groups from
3335 pre to post-training. Finally, the hypothetical food choice task was changed to a card-based game (as
3336 in Porter et al., 2018), rather than the computer-based task used in Study 1.

3337 As described earlier, FoodT is a FSIT app that uses neutral response signals (red and green
3338 circles, similar to the colour-based signals of the FSIT-neutral task of Study 1) that was developed

339 based on FSIT tasks that had been validated in adult samples (e.g., Lawrence et al., 2015). Preliminary
340 work with adults using FoodT at home has revealed that it can reduce self-reported snacking and lead
341 to self-reported weight loss, although the effect is smaller than that observed with web-based
342 training accessed via laptop or desktop computers (Lawrence et al., 2018). FoodT has not yet been
343 tested for its efficacy at changing children's eating behaviours. We decided to test this app directly
344 (rather than reusing the FSIT-neutral task in Study 1) as FoodT is a ready-to-use app that could be
345 delivered immediately to families with children if there is evidence of its effectiveness. Unpublished
346 feasibility studies conducted by our research group have shown that families prefer touchscreen-
347 compatible tasks, which accords with wider trends showing increases in children's use of touchscreen
348 devices such as tablets (Ofcom, 2019). While it would not be possible to isolate the effects of emotive
349 versus neutral signals alone due to other differential features between the two tasks (e.g.,
350 touchscreen versus keyboard response, the use of "filler" stimuli in FoodT, clearer point scoring
351 system in FoodT; see Table 2 below), it would at least be possible to understand whether FoodT
352 produces comparable results to the computer-based task tested successfully in earlier research
353 (Porter et al., 2018). If not, this would indicate that further development and optimisation of the app
354 may be needed.

355 An additional aim was to pilot a measure of food liking that could be used to investigate
356 whether stimulus devaluation also occurs after children complete FSIT. No research has yet
357 investigated the mechanisms of FSIT with children, and this study aimed to make the first steps
358 towards testing the devaluation hypothesis (Veling, Lawrence, et al., 2017) with children. A further
359 outcome measure tested here was whether children's first choice in the hypothetical food choice task
360 was more likely to be a healthy food after FSIT compared to control.

361 Our primary research question was whether the computer-based FSIT task used in our earlier
362 studies (Porter et al., 2018) leads to a larger training effect (versus control) compared to app-based
363 FSIT. We hypothesised that children who completed FSIT (computer or app) would choose a greater
364 number of healthy foods in a time-limited, hypothetical choice task than children who completed a
365 control task. Our secondary research questions were (i) whether children who completed FSIT
366 (computer or app) would rate their liking for energy-dense foods as lower compared to children who
367 completed the control task, and (ii) whether children would be more likely to choose a healthy food
368 as their first choice in the time-limited hypothetical choice task. This study was pre-registered at
369 <https://osf.io/2v7hg/>. Ethical approval was granted by the University of Exeter CLES Psychology Ethics
370 Committee (reference eCLESPsy000031 v4.1).

371 **Materials and Methods**

372 **Participants and Design**

373 This study was of a mixed design with a between-subjects factor with three levels (FSIT-app
374 vs. FSIT-computer vs. Control) and a within-subjects repeated outcome assessment. Two outcome
375 measures were assessed at baseline and post-training (the number of healthy foods chosen in the
376 hypothetical choice task and food liking ratings) while real food choice was measured at the end of
377 the study only.

378 A power analysis conducted using G*Power 3.1.9.2 revealed that a sample of 192 participants
379 would be required to achieve 80% power with an alpha level of 0.05 and a medium effect size ($f = .25^6$
380). As the main hypothesis of interest involved conducting a comparison between each FSIT group and
381 the Control group, the power analysis was conducted for an ANCOVA with two groups and one
382 covariate, with the resulting sample size ($n = 128$) then being multiplied by 1.5 to achieve the correct
383 sample size for a design with two FSIT groups to be compared against a Control group ($n = 192$).

384 Three primary schools in London were approached to participate in the study, with all three
385 responding and consenting. School A had 9.2% of pupils eligible for FSM (national average = 17.3%;
386 ONS, 2020), and was located in the borough of Brent, where in 2018 32.6% of residents were Asian,
387 31.1% were White, 18.9% were Black and the remainder were of Mixed or Other ethnicity. School B
388 had 15.6% of pupils eligible for FSM, and was located in the borough of Southwark where in 2018,
389 61.0% of residents were White, 19.5% were Black, 5.2% were Asian, and the remainder were of Mixed
390 or Other ethnicity. School C had 27.8% of pupils eligible for FSM and was located in the borough of
391 Lambeth, where 52.4% of residents were White, 23.2% were Black, 8.5% were Asian, and the
392 remainder were of Mixed or Other ethnicity. Data on schools was obtained from national and local
393 government websites⁷.

394 Measures and Materials

395 **Go/No-Go Training Task.** As in Study 1, all tasks consisted of stimuli appearing on screen, one-
396 by-one, accompanied by a Go or a No-Go signal. The FSIT-Computer and Control tasks were both
397 programmed using EPrime and delivered via a laptop, and consisted of five blocks of 32 stimuli
398 presentations as in earlier studies. The FSIT-app task was delivered on an Apple iPad and consisted of
399 six blocks of 32 stimuli presentations (two separate games of FoodT, which consists of three blocks
400 per game). This ensured roughly equivalent gameplay time (approximately five minutes) across
401 conditions due to the slightly faster pace of the FSIT-app task.

402 The FSIT-computer task was adapted from Study 1 to contain the same eight healthy food
403 images (Go trials) and the same eight energy-dense food images (No-Go/trials) as the FSIT-app task.
404 These images appeared twice per block in the FSIT-computer task (as in previous studies) but only
405 once per block in the FSIT-app task as this task also presented participants with eight “filler” stimuli
406 (i.e., flowers, clothing, stationery) which were each presented twice per block, once as a Go stimulus
407 and once as a No-Go stimulus. The Control task contained eight sports equipment images (Go trials)
408 and eight technology equipment images (No-Go trials) which were presented twice per block.

409 In the FSIT-app task, the Go signal was a green ring encircling the stimulus and the No-Go
410 signal was a red ring encircling the stimulus. These rings appeared 100ms after stimulus onset and
411 remained on screen for the duration of the stimulus. In the FSIT-computer and Control tasks, the Go
412 signal was a happy emoticon and the No-Go signal was a sad emoticon that appeared at the same

⁶ A meta-analysis of studies performed by our research group with child participants yielded a medium effect size of $d = 0.446$, which translates as $f = .223$. Some of the studies included in this meta-analysis involved group-testing studies, and as noted in Study 1, it was observed that group-work studies produced smaller effect sizes than individual-testing studies. As the current study used an individual-testing methodology, the standard medium effect size of $f = .25$ was used as a closer estimate of the true effect size for this method type.

⁷ Resources consulted = <https://get-information-schools.service.gov.uk/> and <https://data.london.gov.uk/dataset/ethnic-groups-borough>.

413 time as the stimulus and remained on screen for the duration (as before, three different exemplars of
 414 each signal type were used in the two computer-based tasks, with each stimulus being presented with
 415 two variants to encourage Stimulus-Response learning over Stimulus-Signal learning; Best et al.,
 416 2016).

417 There were a number of further differences between the FSIT-app task and the two
 418 computer-based tasks; a summary of the differences between the tasks is presented below in Table 2.
 419 As noted in the introduction to this study, we chose specifically to compare the FSIT-app task against
 420 a version of FSIT that has previously been found to impact children's food choices (e.g., see Porter et
 421 al., 2018). For this reason, the FSIT-computer task was not reprogrammed to accommodate these
 422 differences.

423 *Table 2: Differences between the FSIT-computer and FSIT-app tasks*

	FSIT App	FSIT Computer	Control
Delivery mode	iPad (FoodT)	Laptop (EPrime)	Laptop (EPrime)
Number of blocks	6	5	5
Trials per block	32	32	32
Critical trials per block	16	32	0
Trial length (inter-trial interval)	1500ms (500ms)	1250ms (1000ms)	1250ms (1000ms)
Go trial stimuli	Healthy food (e.g., fruit)	Healthy food (e.g., fruit)	Sports equipment (e.g., goggles, balls)
No-Go trial stimuli	Energy-dense food (e.g., chocolate, crisps)	Energy-dense food (e.g., chocolate, crisps)	Technology (e.g., TVs, games consoles)
Filler stimuli	Yes (clothes, flowers, stationery)	No	No
Response signals	Green versus red circles	Happy versus sad emoticons	Happy versus sad emoticons
Signal delay	Yes (100ms)	None	None
Feedback	Trial-by-trial point scoring presented; End of block feedback Accuracy: % Speed: milliseconds	End of block feedback only; Accuracy: score/32 Speed: seconds	End of block feedback only; Accuracy: score/32 Speed: seconds

424

425 **Hypothetical Food Choice Task.** Following the methods of Porter et al., (2018), children were
 426 presented with twelve cards showing images of food, of which they could choose six. Six of the
 427 presented foods were healthy and six were energy-dense, with four of each food type being different
 428 exemplars of foods presented in training and two being novel, untrained foods. To motivate

429 ecologically valid choices, children were informed that they should choose foods that they really
430 wanted, as they would be getting one of these foods at the end of the experiment. They were also
431 informed that they would be given 30 seconds to complete the task as research has shown that FSIT
432 effects disappear when more time is given for deliberation over choices (Chen et al.); if children
433 completed their choices within 30 seconds, the researcher terminated the task and did not allow any
434 further changes to selections. The researcher verbally informed children that time was running out as
435 the 30 second limit approached.

436 Images were printed on paper, laminated, and cut into sets of cards. Two different image sets
437 were developed and these were counterbalanced among participants from pre- to post-training. The
438 number of healthy foods chosen was the primary outcome measure. The first food that children
439 chose was also recorded as a novel secondary outcome measure. Whilst the images included in the
440 choice tasks were judged to be equally attractive across categories (i.e., healthy and energy-dense) by
441 the research team, they were not systematically matched for palatability and attractiveness as no
442 data currently exists regarding children's ratings of food stimuli. However, the food rating task
443 described below made a first attempt at piloting a measure to obtain this information from children.

444 **Food Liking Rating Task.** Children were presented with twelve images of food, one at a time.
445 As with the food choice images, six showed healthy foods, six showed energy-dense foods. Four of
446 each food type were different exemplars of foods presented in training whilst two were novel,
447 untrained foods. Images in the liking rating task were different to those presented in the hypothetical
448 food choice task. Children were asked to rate each food on a 100-point visual analogue scale (VAS)
449 ranging from "Not at all yummy" all the way up to "Very yummy". The number ratings were not visible
450 on the scale, but a visual aid was available in the form of increasing numbers of stars above the line as
451 it approached the "Very yummy" end (visually, this resembled a "wedge" made up of stars that
452 hovered above the length of the line; see Figure 3).

453 *Figure 3: Visual analogue scale used to rate food liking*

454 [INSERT FIGURE 3 HERE]

455 Children were discouraged from counting the stars and were advised to use the visual aid as a
456 rough guide to prevent them from remembering their rating for a given food from one session to the
457 next. Children pointed to the location on the line that they would rate the food, and the experimenter
458 marked a line with a pen to show where the child's finger had landed. Later, these marks were
459 measured for their location along the line, and converted into a value out of 100. Images were printed
460 on paper, laminated, and cut into sets of cards. The same images were rated at pre and post-training.
461 Again, whilst chosen images across categories were judged to be equally attractive by the research
462 team, they were not systematically matched for palatability and attractiveness as no data currently
463 exists regarding children's ratings of food stimuli. However, this task makes a first attempt at piloting
464 a measure to obtain this information from children.

465 **Hunger Scale.** The five-point hunger scale developed by (Bennett & Blissett, 2014) was used.
466 This depicts a series of teddy bears with increasing amounts of "food" in their tummies, and ranges
467 from "very hungry" to "very full", with an option of "just right" in the middle. Hunger was measured
468 at the start of the second session (i.e., the training session) only, as previous work has suggested that

469 hunger levels may influence the efficacy of the training task (Veling, Aarts, & Stroebe, 2013). Lower
470 scores indicated greater hunger, while higher scores indicated increasing fullness.

471 **Real Food Choice.** Children were offered a selection of snacks from which they could choose
472 one food to take home as a participation reward. The options included fruit (apple, orange, small
473 bunch of green grapes) and energy-dense snacks (medium-sized Kinder chocolate bar, Nairn's gluten-
474 free chocolate chip biscuits, Walker's baked crisps). An example of each food was placed on a paper
475 plate, (the actual foods that children would be given were kept in staffroom refrigerators or in a cool
476 bag), and these example options were kept covered by a tea towel until the real food choice task
477 began. Children chose one option (this choice was noted as an outcome measure) and were
478 subsequently also allowed an extra choice of one piece of fruit (to ensure all children went home with
479 at least one piece of fruit). No time limit was imposed on this task. Children's choices were placed in
480 paper bags, stapled closed with a debrief letter for parents attached, and handed to teachers at the
481 end of the day.

482 **Debrief and awareness assessment.** Children were asked a series of questions to assess their
483 awareness of the aims of the project: (i) what they thought the games they had played were about,
484 (ii) why they thought they had played them, (iii) if they could remember which pictures (Control) or
485 foods (FSIT) they had to press during the computer/iPad game and finally (iv) if they thought that the
486 computer/iPad game might have changed which foods they wanted. Children's answers were coded
487 as aware/unaware for the following: (i) awareness of contingencies, (ii) awareness of healthy eating
488 purpose and (iii) awareness of task effects on food choices.

489 **Procedure**

490 Letters were sent home to parents, containing a brief description of the study aims and
491 procedures, and a consent form for parents to return to school. Only those children whose parents
492 consented to participation were invited to take part in the two experimental sessions. All children
493 worked with the researcher individually. In the first session, children were asked if they assented to
494 playing a few quick games about their favourite foods. Upon assent, children completed the
495 hypothetical food choice task to record their baseline food preferences. Next, they completed the
496 food liking rating task before returning to the classroom. In total, Session 1 lasted for approximately
497 five minutes.

498 The second session took place during the following school week. Children were again asked if
499 they assented to participating. The second session began with children assessing their current level of
500 hunger using the hunger scale, before completing the Go/No-Go training task that they had been
501 allocated to. Immediately following the training task, children completed the hypothetical food choice
502 task and then the food liking rating task. The order of these tasks remained fixed due to food choices
503 being our primary outcome measure. Once these tasks had been completed, the experimenter
504 presented children with the real food choice task, and asked children to choose one item to take
505 home as a thank you for taking part. After their choices had been made, children were asked the
506 awareness questions and were debriefed before returning to the classroom.

507 **Data preparation and analyses**

508 Planned exclusion criteria included overall accuracy on the Go/No-Go task below 60%, No-Go
509 accuracy below 50%, and average reaction times (RTs) beyond three standard deviations of the
510 condition group mean.

511 To check whether the food pictures presented in the liking rating task were well matched,
512 repeated measures ANOVAs were conducted with a 2 (food type: healthy versus energy-dense) by 2
513 (included in FSIT tasks versus novel) design. This analysis was conducted as a preliminary check
514 considering that, as noted above, stimuli were not systematically matched for palatability and
515 attractiveness as no data currently exists regarding children's ratings of food stimuli.

516 Repeated measures ANOVAs were used to investigate reaction times on Go trials and No-Go
517 commission errors across blocks. For the FSIT-app condition (for which six blocks of training were
518 completed), only the first five blocks were entered into analyses so that comparisons could be made
519 across conditions. Where the assumption of sphericity was violated, corrections were used
520 (Greenhouse-Geisser where $\epsilon < .75$, Huynh-Feldt otherwise). The data from the FSIT-app
521 condition was also analysed in repeated measures ANOVAS to see whether reaction times and error
522 rates across blocks differed for food stimuli (which were presented with constant stimulus-response
523 associations) versus filler stimuli (50/50 stimulus-response associations). This allows us to
524 differentiate between performance improvements based on general task practice versus those based
525 on learning specific stimulus-response (go or no-go) associations (e.g., Lawrence et al., 2015).

526 The effect of training group on hypothetical food choices was explored using an ANCOVA
527 model, with baseline choices entered as a covariate and post-training choices as the outcome
528 measure. Pairwise comparisons were conducted to investigate differences between the three groups
529 (these were unadjusted as they replicated earlier findings). Bayes factors for each FSIT versus Control
530 comparison were calculated using the method and calculator described in Study 1. Paired samples t-
531 tests were conducted for each condition separately to test the change in number of healthy foods
532 chosen between the two measurement points. Binary logistic regression models were analysed to test
533 whether children in the two FSIT groups (compared to the Control group) were more likely to choose
534 (i) a healthy food as their first choice in the hypothetical food choice task, and (ii) a healthy food as
535 their real food participation reward.

536 Food liking rating was analysed with repeated-measures ANOVAs, including the within-
537 subjects factors of food health status (healthy versus energy-dense) and time (baseline versus post-
538 training), with condition as a between-subjects factor. We had also planned to include a within-
539 subjects factor indicating whether foods had been included in the FSIT tasks (included versus novel),
540 however baseline analyses indicated that included versus novel foods were not well matched and
541 could not therefore serve as an appropriate comparison (see below).

542

Results

543 Preliminary Analyses

544 In total, 219 children (115 female) aged 4-10 years ($M = 6.64$, $SD = 1.80$) were randomised to
545 the FSIT App ($n = 72$), FSIT Computer ($n = 73$) and Control ($n = 74$) groups. Thirteen were excluded due
546 to either low Go/No-Go task performance accuracy (i.e., lower than 60%; $n = 8$) or absence from

547 school during the second session ($n = 5$). The data from 206 children (106 female) aged 4-10 years (M
548 $= 6.77$, $SD = 1.76$) were retained.

549 The three training groups (FSIT-app, FSIT-computer and Control) were well balanced with
550 regards to age, gender, baseline food choices, baseline ratings for each of the four food types (healthy
551 trained, healthy novel, energy-dense trained and energy-dense novel), and hunger during the training
552 session (Table 3).

553 *Table 3: Group demographic characteristics and baseline outcome measures. For Gender, frequencies*
554 *of female participants are noted with percentage of group in brackets. All other variables are*
555 *described in terms of mean averages, with standard deviations in brackets.*

	App ($n = 70$)	Computer ($n = 69$)	Control ($n = 67$)
Age	6.99 (1.80)	6.62 (1.71)	6.69 (1.79)
Gender - n female (%)	37 (52.9)	30 (43.5)	39 (58.21)
Healthy-food choices	2.54 (1.21)	2.87 (1.45)	2.57 (1.29)
Healthy trained rating	72.60 (18.41)	71.68 (20.62)	69.14 (21.30)
Healthy novel rating	58.68 (27.70)	54.71 (31.34)	57.44 (30.76)
Energy-dense trained rating	74.18 (19.11)	77.30 (18.42)	71.10 (21.79)
Energy-dense novel rating	79.72 (20.61)	77.88 (21.99)	75.11 (21.87)
Hunger	2.57 (1.27)	3.04 (1.39)	2.85 (1.47)

556

557 Baseline Food Ratings

558 At baseline, a significant effect of health status was found ($F_{1,203} = 45.17$, $p < .001$, $n^2_p = .182$),
559 with healthy foods being rated as liked less than energy-dense foods. Foods that were included in the
560 training were liked more than the novel foods ($F_{1,203} = 21.188$, $p < .001$, $n^2_p = .095$), suggesting that
561 the novel stimuli chosen in this study were not well matched (no exposure to the training task had
562 occurred at this point). Due to these unintended baseline differences in liking for foods included in
563 the training versus novel foods, subsequent analyses only focused on those foods that had been
564 included in the training, as the novel foods could not be used for comparison.

565 Training Performance

566 Reaction times (RTs) got significantly quicker over blocks ($F_{3,28,659.282} = 42.03$, $p < .001$, $n^2_p =$
567 $.173$). A significant effect of condition was found, ($F_{2,201} = 34.29$, $p < .001$, $n^2_p = .254$) with slower RTs
568 for participants in the FSIT-app condition ($M = 884.93$, $SE = 16.83$) compared to participants in both
569 the FSIT-computer ($M = 703.79$, $SE = 16.83$, $p < .001$) and control ($M = 726.19$, $SE = 17.20$, $p < .001$)
570 groups. A significant interaction between block and condition ($F_{6,56,659.282} = 3.08$, $p = .004$, $n^2_p = .030$)
571 was also observed, with simple effects analyses revealing that improvements in RTs over blocks were
572 strongest for the FSIT-app group ($F_{4,198} = 18.42$, $p < .001$, $n^2_p = .271$), followed by the FSIT-computer
573 group ($F_{4,198} = 7.22$, $p < .001$, $n^2_p = .127$) and finally the control group ($F_{4,198} = 2.88$, $p = .005$, $n^2_p =$
574 $.073$).

575 Commission errors decreased over blocks ($F_{3,655,730.966} = 11.107$, $p < .001$, $n^2_p = .053$), and a
576 significant effect of condition ($F_{2,200} = 11.41$, $p < .001$, $n^2_p = .100$) revealed lower error rates in the

577 FSIT-app group ($M = .031$, $SE = .007$) compared to the FSIT-computer ($M = .067$, $SE = .007$, $p = .001$)
 578 and control ($M = .072$, $SE = .007$, $p < .001$) groups. No significant interaction was observed for this
 579 analysis.

580 In analyses on FSIT-app data only, there was no evidence of an effect of Stimulus Type (food
 581 vs. filler) on RTs, nor was there evidence of an interaction between Stimulus Type and Block for RTs
 582 (both $p < .200$). Commission errors were significantly higher for filler stimuli ($M = .055$, $SE = .007$) than
 583 for energy-dense food stimuli ($M = .028$, $SE = .005$; $F_{1,67} = 33.45$, $p < .001$, $\eta^2_p = .333$), suggesting
 584 participants learned food-No-Go associations as expected. No interaction was found between block
 585 and stimulus type for commission errors.

586 Food Choices

587 Post-training healthy-food choices differed significantly between conditions ($F_{2,202} = 5.74$, $p =$
 588 $.004$, $\eta^2_p = .054$) with the highest healthy-food choice in the FSIT-computer group ($M = 2.78$, $SE = .16$)
 589 followed by the FSIT-app group ($M = 2.42$, $SE = .16$) and finally the control group ($M = 2.02$, $SE = .16$).
 590 Planned pairwise comparisons revealed that the only significant difference existed between the FSIT-
 591 computer group and the Control group ($p = .001$), with the comparison between the FSIT-app and
 592 Control groups failing to pass the significance threshold ($p = .077$). There was no significant difference
 593 between either of the two FSIT groups either ($p = .103$). Bayes factors show that the data indicates
 594 strong support for a difference between the control group and the FSIT-computer task ($BF = 210.98$)
 595 but that the data are inconclusive for the FSIT-app task ($BF = 1.80$).

596 Paired sample t-tests revealed that the effect of condition was primarily driven by a decrease
 597 in healthy-food choice in the Control condition across time-points (Figure 4). Comparing baseline food
 598 choices to post-training food choices revealed no evidence of change in the FSIT-app ($p = .334$) or
 599 FSIT-computer ($p = 1.000$) groups, but a significant effect of time was found in the Control group ($t_{66} =$
 600 3.56 , $p = .001$) with choices at post-training ($M = 1.99$, $SD = 1.32$) being significantly lower than those
 601 at baseline ($M = 2.57$, $SD = 1.29$).

602 *Figure 4: Mean number of healthy foods chosen at baseline and post-training within each condition;*
 603 *error bars show standard error*

604 [INSERT FIGURE 4 HERE]

605 Binary logistic regression revealed that compared to the Control group, participants in the
 606 FSIT-computer group were significantly more likely to select a healthy food as their first choice in the
 607 post-training hypothetical choice task ($B = 0.85$, $SE = 0.40$, $Wald X^2 = 4.56$, $OR = 2.34$, $p = .033$). There
 608 was no effect of the FSIT-app task on likelihood of choosing a healthy food as the first choice at post-
 609 training ($p = .532$).

610 Across the entire sample, only 14.8% of children chose a healthy food in the real choice
 611 reward task and when examining the effect of condition on real food choices, there was no significant
 612 effect of completing either the FSIT-app or FSIT-computer training compared to the Control task (both
 613 $p > .300$).

614 Food Liking Ratings

615 These analyses were conducted for trained foods only, due to the finding that trained foods
616 and novel foods were not well matched at baseline. Healthy foods were rated slightly lower ($M =$
617 70.95 , $SE = 1.38$) than energy-dense foods ($M = 74.78$, $SE = 1.25$, $F_{1,197} = 4.66$, $p = .032$, $\eta^2_p = .023$) but
618 no further significant main effects or interactions were observed. For healthy foods, a slight decrease
619 in liking was observed for the FSIT-app group and the Control group, whereas a slight increase was
620 observed in the FSIT-computer group (Figure 5). The opposite patterns were observed for unhealthy
621 items, with liking ratings decreasing slightly in the FSIT-computer group and increasing slightly in the
622 FSIT-app and Control group. However, none of these differences or changes reached significance (all p
623 $> .130$).

624 *Figure 5: mean change (plus standard error) from baseline to post-training in food liking ratings for*
625 *healthy foods and energy-dense foods*

626 *[INSERT FIGURE 5 HERE]*

627 **Effect of Awareness**

628 One-hundred-and-eighty-six children in the sample were interviewed at the end of their
629 involvement with the project (some children were not interviewed either due to time constraints or
630 due to difficulties maintaining attention i.e., for very young children). The majority of children were
631 aware of task contingencies ($n = 152$) but awareness of the healthy-eating aims of the study and task
632 effects were much lower ($n = 62$ and 39 respectively). Chi-squared tests revealed that there were no
633 significant differences between groups for any of the awareness measures (all $p > .480$). In addition,
634 adding these variables to the ANCOVA investigating the effect of training on food choices revealed
635 that none were predictive of food choices (all $p > .290$), while the effect of condition remained
636 significant ($p = .004$).

637

638

Discussion

639 In this study, we tested a FSIT-app against the FSIT-computer task we have used in previous research
640 (Porter et al., 2018). We hypothesised that children playing the two FSIT tasks (app or computer)
641 would choose a greater number of healthy foods compared to children playing the Control task. We
642 were also interested in whether there would be any preliminary evidence for differences in effect
643 sizes of these respective FSIT tasks (when each was compared to the Control task). Our findings
644 partially support our hypothesis; children in the FSIT-computer group chose a significantly greater
645 number of healthy foods in the post-training hypothetical food choice task, and were also more likely
646 to select a healthy food as their first choice in this task. In addition, within-group analyses showed
647 that healthy-food choices in the control group decreased over time, whereas they remained stable in
648 the two FSIT groups. This suggests that FSIT can have a beneficial effect on healthy eating behaviours.
649 Whilst there was a trend for children in the FSIT-app group to choose a greater number of healthy
650 foods than children who had played the control task, this difference was not significant. The within-
651 group analyses showed that the FSIT-app group also appeared to be protected from the decline in
652 healthy-food choices observed in the Control group, however the lack of significant differences at
653 post-training means that no definitive conclusions can be drawn regarding the effects of this task on
654 food choices.

698 would talk during the task despite efforts to keep the room quiet, and they could also turn around
699 and see that their peers were playing a different version of the task than themselves. This is reflected
700 in the data – examining children's performance data on the emotive-FSIT task (i.e., the only version of
701 FSIT that we had tested beforehand, and with success) showed that commission error rates were
702 unexpectedly high. Children may also have been influenced by each other during the food choice task
703 itself – some items were clearly very popular, and some children would exclaim in delight upon
704 finding them in the choice task. Children are influenced by the food preferences of their peers (Birch,
705 1980; DeJesus, Shutts, & Kinzler, 2018) and this social endorsement by peers may have overridden
706 FSIT effects on food choices.

707 In comparison, children in Study 2 participated on a one-on-one basis, as in our own earlier
708 research and that of others (Folkvord et al., 2016). This time, a significant effect of training was
709 observed once more for the FSIT-computer task, which is the same task that has been successfully
710 tested in earlier research. Unlike in Study 1, children's task performance did not appear to be
711 negatively impacted in this study. This suggests that low commission error rates during FSIT may be
712 important for subsequent training effects on food choices, which dovetails with meta-analyses of
713 studies in adult participants, where it was found that successful stopping on inhibition trials was
714 necessary for FSIT to have an impact on eating behaviour (Jones et al., 2016). To explore this, we
715 conducted an exploratory correlation on the data collected in Study 2 which indicated that changes in
716 commission errors were negatively correlated with changes in healthy-food choice ($R = -.223, p =$
717 $.009$) - in other words, improvements in inhibition to energy-dense foods in the FSIT training tasks
718 were associated with increases in healthy-food choices.

719 These findings suggest that lower commission error rates lead to stronger FSIT effects on
720 eating behaviour. However, in Study 2, FSIT-computer training appeared to be more effective than
721 FSIT-app training, despite the computer task having significantly higher commission error rates than
722 the app task. This could be due to differences in commission error measurement sensitivity as a result
723 of the response mode (touchscreen taps versus keyboard press). The computer task left little room
724 for error (i.e., because children's hands were resting on computer keys, meaning that even very tiny
725 movements can result in a "press") and was thus a highly-sensitive measure of commission errors.
726 Comparatively, for the app task, the resting position of children's hands was further away from the
727 response apparatus (it is not possible to play the FSIT-app task with the hand resting on the screen).
728 The greater distance between hand and device may then lead to the recording of artificially low error
729 rates (i.e., because there is more time to correct errors on the hand's comparatively long journey
730 towards a touch screen). Future research could explore this possibility, and could also investigate
731 whether these task differences impact children's engagement with FSIT. For example, the increased
732 challenge of computer-based tasks may engage children's attention and motivation, and compel them
733 to improve their scores and focus on learning the rules of the game. However if the game is less
734 challenging (i.e., because motor responses can be corrected at relative leisure), then there may be
735 less drive to improve performance. The findings of these studies together indicate that such
736 motivation and attention may be key for FSIT effects on eating behaviour.

737 Altogether, the results of these studies suggest that high task performance is required for
738 FSIT to have an impact on eating behaviour outcomes, and that this may be achieved by
739 implementing training in a controlled and quiet environment. One potential alternative explanation
740 for the difference between studies is that individual testing results in demand characteristics, with

741 children more likely to try and please the experimenter when they are working on a one-on-one basis.
742 In Study 2 we found no significant differences between groups regarding awareness of the study aims,
743 task contingencies, or task effects on food choices/liking. Awareness of the healthy-eating aims and
744 expected task effects were low, although awareness of contingencies within the task was high.
745 Children in the control group who were considered “aware” of the study’s aims and task
746 contingencies described how they needed to press for the “healthy” activity images (sports), and not
747 for the “unhealthy” activity images (technology). This suggests that the control task could also have
748 driven any demand characteristics within the sample, rather than this being limited to the active
749 group only.

750 However, if children were simply choosing foods based on what they believed the
751 experimenter wanted them to choose, healthy-food selection rates would surely be much higher than
752 they are and similar across all conditions. However, very few children chose a high number of healthy
753 foods (and barely any selected a healthy food as their real choice), further suggesting that demand
754 characteristics were not driving these results. Both studies found a decline in healthy eating
755 behaviour across time – this occurred in all groups in Study 1, and in the Control group only in Study
756 2. Turton and colleagues, who also observed a decline in the healthiness of participants’ eating
757 behaviour over experimental sessions, suggested that such patterns may be due to participants
758 becoming more familiar with the experimental environment and becoming more relaxed in their
759 eating behaviours (Turton et al., 2018). Relatedly, children being offered a snack of their choice in the
760 middle of the school day (Study 2 only) would have been a departure from their usual routine, and
761 may have been seen as a rare chance for them to indulge in a “treat”. In this sense, children may have
762 been in a more disinhibited state than they would normally when choosing which foods to eat.
763 Understanding the wider context of children’s eating behaviours (e.g., whether they had already
764 eaten fruit that day, how often they were allowed energy-dense foods at school and at home etc.)
765 would help to better contextualise these findings.

766 While the finding of a decline over time departs from previous findings (i.e., Porter et al.,
767 2018 found an increase in healthy-food choice in the FSIT group and no change in healthy-food choice
768 in the control group), this could be due to children in the current study choosing a higher percentage
769 of healthy foods at baseline. An earlier study by our research group (Porter et al., 2018) saw healthy
770 choices rise significantly in the FSIT group from 36% to 52%, whereas in the present study, they were
771 higher at baseline (42-48%) but remained stable to post-training (40-48%). Meanwhile, healthy
772 choices in the earlier study’s two control groups remained stable from baseline (29-36%) to post-
773 training (32-39%) whereas in the present study, baseline choices in the Control group were higher
774 (43%) but then significantly declined to a more comparable 33% at post-training. This suggests that
775 the starting point for children’s food choices could be key for determining whether FSIT has an
776 augmentative effect (i.e., increases healthy-food choice) or a protective effect (i.e., guards against a
777 decline in healthy-food choice); when healthy-food choices are low at baseline then FSIT has the
778 potential to increase them but when healthy-food choices are high at baseline, FSIT can maintain this
779 behaviour.

780 These studies have a number of strengths; firstly, they provide further support for the use of
781 FSIT as a healthy eating intervention for use with children. Study 2 also piloted a FSIT app with
782 children for the first time and provides preliminary, tentative evidence that this app may be able to
783 support healthy eating habits in children (i.e., by protecting against the observed decline in healthy

784 behaviours over time). As FSIT can be delivered as a DBCI directly to users' devices (such as via the
785 FoodT app), this intervention can be used immediately and for free by families. A further advantage is
786 that the flexibility that DBCIs afford users means that recommendations for usage based on the
787 findings of this study (i.e., to preferably play the app in a quiet environment) can be implemented in a
788 way that suits them. The smaller effect size for this app (in comparison to computer-based FSIT)
789 suggests that further research needs to be conducted to identify the reasons for this, and potential
790 developments to optimise app-based training should be identified. A further strength of this study is
791 that a food liking rating scale was successfully piloted which could be used in future research to
792 pursue the question of whether the stimulus devaluation contributes to FSIT effects on children's
793 eating behaviour as well as adults'.

794 Nevertheless, a number of limitations should also be noted. Most notably, the question of
795 whether evaluative conditioning can bring additional benefits to FSIT paradigms has not been fully
796 answered. In Study 1 (in which we could directly compare neutral and emotive No-Go signals), no
797 training effects were observed. In Study 2 (in which training effects were observed), the two FSIT
798 tasks differed in a number of ways beyond the response signals used, and therefore the relative
799 contribution of these various factors cannot be teased apart. For example, a further potentially crucial
800 difference between the app and computer tasks is the proportion of critical "food-response" trials per
801 block – in the app this comes to 50% of all trials (plus 50% "filler" trials) whereas in the FSIT-computer
802 task, 100% of trials encouraged a food-response association. Therefore, the level of exposure to
803 stimulus-response associations was lower in the FSIT-app group compared to the FSIT-computer
804 group, which may have impacted the efficacy of this task variant. Earlier research with children
805 (Porter et al., 2018; Folkvord et al., 2016) has found significant, positive effects of FSIT using tasks that
806 do not contain these fillers, suggesting that simpler tasks with a higher proportion of food-response
807 trials may be most effective for children. Future research should aim to test the influence of these
808 various factors (including the use of emotive versus neutral response signals) in tasks that more
809 closely control for other differences. A second limitation is that the researcher who delivered the
810 intervention, recorded the outcome measures and performed the statistical analysis was not blinded
811 to condition allocation. Finally, current results do not help to answer the question of how long any
812 FSIT effects on food choices might last for, and whether effects can be reinforced by repeated training
813 sessions. A more longitudinal design, such as that used by Study 1, would help to explore this
814 question.

815 Future research should aim to investigate whether repeated use of FSIT at home can have a
816 significant impact on real-life eating behaviour, as has been found to be the case with adult
817 participants. While the outcome measures used here are useful for gathering preliminary evidence on
818 FSIT effects within a controlled environment, their ecological validity is questionable. For example, the
819 hypothetical food choice task (when implemented as in Study 2) does not allow children to change
820 their choices after they have made their initial selections. It is questionable whether this is truly
821 representative of children's daily feeding decisions compared to tasks in which they are allowed (at
822 least some) time to deliberate over their choice and select an alternative if they change their minds.
823 Work with adults has suggested that the effect of response training paradigms may be limited to
824 choices made under time-pressure. While this could be a further explanation for the lack of effects in
825 the real food choice task, it also has clear implications for the applied value of this paradigm as a
826 healthy eating intervention. Folkvord et al., (2016) found an effect of FSIT on calorie intake without

827 time pressure, however no studies have yet investigated the impacts of FSIT on children's real life
828 eating behaviour outside of an experimental setting.

829 Conclusion

830 To conclude, the studies presented here provide some further support for the efficacy of FSIT as a
831 healthy eating tool for children. Accuracy on energy-dense No-Go trials appears to be important for
832 FSIT effects on eating behaviour, and conditions that reduce children's attention or motivation (such
833 as noisy, distracting environments) may subsequently reduce training effects on food choices. Future
834 research should explore whether app-based versions of FSIT can be optimized (i.e., by increasing the
835 level of challenge) to increase the efficacy of this delivery mode, and whether FSIT effects on food
836 choices can translate into real life eating behaviour over longer time periods.

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