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Social influence effects on food valuation generalize based on conceptual similarity

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Author Note

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Abstract

Opinions of others influence behavior and decision-making, with important consequences for health. An unaddressed question is whether and how social influence can generalize across different situations or decisions. From a learning perspective, generalization is the transfer of previously acquired information to new stimuli and can be based on both perceptual and conceptual similarity. Here, we test whether social influence generalizes to new choices based on shared conceptual features, such as the healthiness and tastiness of different food items. We conducted three studies (total N = 468), in which healthy participants rated how much they would like to eat different food items and were subsequently presented with the ratings of several other people ('social ratings'). Unbeknownst to our participants, they were randomly assigned to social ratings that either reflected a mainly health-driven valuation of food items ('health group') or to social ratings that reflected a taste-driven valuation of food items ('taste group'). The results in all three studies showed that participants' food ratings became more influenced by healthiness in the 'health group' than in the 'taste group'. In one study, these effects further transferred to food choices in a naturalistic supermarket task. Our findings provide first evidence of generalization of social influence effects based on inferred social health norms. Futures studies could test conceptual generalization of other types of social and non-social learning and characterize the brain mechanism underlying these effects.

Keywords: *social influence, food valuation, dietary decision-making, generalization, learning*

Social influence effects on food valuation generalize based on conceptual similarity

67

68 Human behavior is strongly influenced by social and cultural context. A prominent
69 example are food choices and eating behavior. Some of these social norms are relatively
70 stable and strict. We are likely used to eat beef if we have grown up in Argentina or in Japan,
71 but we would be repelled by the idea if we were Hindu. Other social norms may be more
72 subtle, evolve over time, and vary between different subcultures or even smaller groups. For
73 example, even if we usually like to eat steak with fries, we might choose something different if
74 we go to the restaurant with a new group of friends that are health-conscious and/or concerned
75 about climate change. How do humans learn about and adapt their behavior to implicit social
76 norms?

77 Many experimental studies show that food choices are influenced by the observed
78 behavior of other people (Higgs, et al., 2015). For example, when people eat together with
79 someone eating a large amount, people are more likely to consume more than when they eat
80 alone (Cruwys et al., 2015). Food preferences are influenced by the ratings of even
81 anonymous peers (Nook & Zaki, 2015), and even non-human primates have been shown to
82 choose food in line with observed group norms (Van de Waal et al., 2013). Social influence
83 effects are thus an important factor when making food choices and may interact with other
84 factors known to be important, such as taste and health considerations (Rangel, 2013; Sobal
85 et al., 2006; Steptoe et al., 1995). Further, epidemiological and social network studies have
86 shown that a person's chance of becoming obese increases with the number of social contacts
87 who are obese (Christakis & Fowler, 2007), and that social influence is the strongest driver of
88 changes in diet (Eker et al., 2019). This suggests that, over time, even small social and cultural
89 influences on food choices may have important consequences for health (Fischler & Masson,
90 2008).

91 An important but unaddressed question is whether and how social influence may
92 generalize across different situations and across different foods that share common features.
93 Previous studies have typically tested whether people's behavior is influenced by specific
94 observation of others' behavior, such as whether they become more likely to choose the salad
95 over the steak if others have chosen the salad. However, social and cultural influences likely
96 operate in more general and abstract ways. For instance, we might not choose the same salad
97 but something else that is also in line with the inferred values and norms of the group—such
98 as a vegetable soup. Here, we test the idea that social influence can generalize across food
99 choices based on abstract conceptual dimensions such as healthiness and tastiness of food
100 items.

101 From a learning perspective, generalization can be defined as the transfer of previously
102 acquired information to new stimuli and situations, based on the similarity between the original

103 and a new situation (Guttman & Kalish, 1956). Generalization was already noticed by Pavlov
104 (1927) in his classic conditioning experiments with dogs where he associated food with the
105 sound of a bell and noticed that the animal's reaction generalized to other similar sounds.
106 Subsequently, other scientists have obtained empirical "stimulus generalization gradients",
107 which relate the probability, speed, or strength of a learned response to the difference between
108 the test and training stimuli (Guttman & Kalish, 1956; Shepard, 1987). Generalization does
109 not necessarily reflect a lack of discrimination between learned and new stimuli. Instead,
110 generalization can be seen as an active process of associating a stimulus to a more general
111 underlying pattern or rule, which is adaptive in a world where situations are often similar but
112 rarely identical (Shepard, 1987). Accordingly, generalization follows both perceptual similarity
113 gradients as well as conceptual relationships (Dunsmoor & Murphy, 2015). Thus,
114 generalization allows people to learn not only about specific stimuli but to infer more general
115 norms and apply them to novel contexts to adapt (Behrens et al., 2018).

116 Here, we tested whether similar conceptual generalization mechanisms could apply to
117 social influence effects. Recent brain imaging studies suggest parallels between social
118 influence and reinforcement learning, demonstrating that agreeing with others evokes activity
119 in reward-related brain areas (Campbell-Meiklejohn et al., 2010; Klucharev et al., 2009; Zaki
120 et al., 2011). Disagreeing with others is associated with activity in brain areas related to error
121 processing and cognitive conflict (Klucharev et al., 2009; Koban et al., 2014), leading to
122 subsequent adjustments in behavior and decision-making to reduce this kind of social conflict
123 (Klucharev et al., 2009). If social influence is based on partially similar mechanisms as
124 reinforcement learning, then it may also generalize based on perceptual and conceptual
125 features.

126 Food choices naturally lend themselves for testing this idea. As other types of
127 decisions, valuation of food items can be described as a function of different attributes and the
128 importance (weight) of these attributes for any given individual. Two of the most important
129 attributes when evaluating food are its tastiness and its healthiness (Rangel, 2013) and the
130 importance of these attributes varies substantially across individuals and situations (Hare et
131 al., 2011; Schmidt et al., 2018). We hypothesized that social influence on food choices can
132 generalize by shifting how much people weight health and taste attributes. Thus, we predicted
133 that, during observation of other people's food ratings, people implicitly infer underlying social
134 norms regarding the importance of health and taste, which then influence their own food
135 choices.

136 For this purpose, we developed a novel social influence task in which participants rated
137 how much they would like to eat different food items, first during a baseline phase without
138 social information, then during a social influence phase (**Figure 1A**). During the social
139 influence phase, they were presented with the ratings of several other people ('social ratings')

140 after their own food rating. For each food item, two sets of social ratings were selected to
141 create two different experimental groups (**Figure 1B**). One group of participants (the *Health*
142 group) was presented with social ratings that reflected a preference for healthy food items
143 (i.e., ratings were selected based on high weights of health and low weights of taste). The
144 other group was presented with social ratings that reflected a low weighting of health and a
145 high weighting of taste aspects of the food (*Taste* group). If participants generalize from the
146 social ratings, then participants in the *Health* group should increase the importance (or weight)
147 of health attributes compared to the *Taste* group in the social influence phase (**Figure 1C**).
148 Participants in the *Taste* group in contrast should increase the importance of taste attributes
149 compared to the *Health* group. We tested these hypotheses in three different studies, with
150 different food stimuli and across two different countries. Further, in order to investigate the
151 possible transfer of generalized social influence to another task, we implemented an additional
152 online supermarket task (2006; Lai et al., 2020) in Study 2 and 3, providing a measure of
153 participants' food preferences closer to how they make food choices in the real world (**Figure**
154 **1A**). We expected that participants in the *Health* group would still be more guided by food
155 healthiness than the *Taste* group and thus buy healthier food products in the supermarket
156 (**Figure 1C**).

157

158

159 Results

160 Study 1

161 The first experiment tested the generalization of social influences on self-reported food
162 preference ratings in 196 adult participants of an online study. **Figure 2A** illustrates the time
163 course of participants' individual health and taste weights (i.e., beta estimates) during baseline
164 (T0) and the five bins of trials during the social influence phase (T1-T5). Each bin consisted of
165 16 trials that were balanced regarding the healthiness and tastiness of the 16 food items. This
166 allowed us to assess how participants weighted health and taste in their food ratings in each
167 bin and in each phase (over multiple bins), by fitting a multilevel general linear model (GLM)
168 with healthiness and tastiness of food items as predictors and food preference ratings as the
169 outcome variable. This multi-level model yielded beta-weights for the taste and the health
170 regressors for each participant, with larger beta-weights indicating greater importance of the
171 regressor in predicting food preference ratings.

172 While the two groups had similar health weights during the baseline phase, they
173 diverged during the social influence phase (see **Figure 2A-B**). In line with our prediction,
174 during the social influence phase and controlling for baseline weights, the *Health* group
175 ($N_H=97$, $M=0.04$, $STD=0.40$) placed significantly more weight on health than the *Taste* group
176 ($N_T=99$, $M=-0.08$, $STD=0.38$), $t(193)=4.12$, $p<0.001$, Cohen's $d=0.60$. This suggests that

177 participants adapted their food ratings to implicit social norms regarding the importance of
178 health considerations, depending on their experimental group. In contrast, there was no
179 significant difference in taste weights between the *Taste* ($M=0.74$, $STD=0.50$) and *Health*
180 ($M=0.90$, $STD=0.59$) groups during the social influence phase, controlling for baseline,
181 $t(193)=-1.25$, $p=0.21$, Cohen's $d=0.18$ (see **Figure 3A-B**). This suggests that social influence
182 may generalize less based on the tastiness dimension.

183

184 **Study 2**

185 The second online experiment aimed to replicate the results of Study 1 in a different
186 data set from a different country (France, $N=205$) and using a different set of food items. The
187 time courses of healthiness beta weights for the two groups are shown in **Figure 2C**.
188 Paralleling the findings of Study 1, the *Health* group ($N_H=103$, $M=5.03$, $STD=8.23$) had
189 significant higher healthiness weights during the social influence phase than the *Taste* group
190 ($N_T=102$, $M=2.32$, $STD=8.69$), controlling for baseline weights, $t(202)=-2.00$, $p=0.047$,
191 Cohen's $d=0.28$ (see **Figure 2D**). As in Study 1, there was no significant difference between
192 the *Taste* ($M=12.20$, $STD=7.17$) and *Health* ($M=10.71$, $STD=6.58$) groups for the tastiness
193 weights during the social influence phase, $t(202)=1.08$, $p=0.28$, Cohen's $d=0.15$ (see **Figure**
194 **3C-D**).

195 Study 2 further tested whether the generalization of social influence would transfer to
196 food choices in an ecological online grocery store task (Howe's Grocery [https://openscience-
197 onlinegrocery.com/](https://openscience-onlinegrocery.com/)), in which participants were instructed to select foods for next day's
198 breakfast and some snacks. To measure the healthiness of participants food choices in the
199 supermarket task, we computed the average 'health star points' (an objectively defined
200 measure of food healthiness, as implemented in the experimental online grocery store) of
201 selected products in participants' basket. We first tested whether participants' health
202 preferences in the food rating task was consistent with their food choices the supermarket
203 task. Indeed, we found a positive and significant correlation between the healthiness beta
204 weights during the social phase and objective health score of the selected products in the
205 online supermarket ($r(203)=0.34$, $p<.001$, see **Figure 4A**). Thus, participants whose food
206 ratings were more driven by the healthiness of food items during the social learning task also
207 made healthier food choices in the online supermarket task, supporting the consistency of
208 both measures. However, in contrast to our hypothesis, the *Health* group ($M=0.43$) did not
209 select significantly healthier food items (i.e., items with higher health star points) in the
210 supermarket task compared to the *Taste* group ($M=0.49$), $t(203)=-0.11$, $p=0.913$, Cohen's
211 $d=0.02$ (see **Figure 4C**). Thus, in Study 2, the learning from the main task did not significantly
212 transfer to this second, supermarket task.

213

214 **Study 3**

215 The aim of the third study was to replicate the generalization of social influence effects
216 in an in-person laboratory study (N=64 participants). This allowed us to use willingness-to-pay
217 (WTP) as an incentive-compatible measure of how much participants valued the food items,
218 by using a second price auction to actually implement one of their food choices (see Methods
219 and Plassmann et al., 2007 for details), thus reducing the influence of demand effects on
220 changes in food preferences.

221 Time courses of health weights are shown in **Figure 2E**. As in the two previous studies,
222 during the social influence phase (controlling for baseline), the *Health* group (N_H=32, M=0.19,
223 STD=0.16) put significantly greater weights on the healthiness of food items than the *Taste*
224 group (N_T=32, M=0.10, STD=0.16): $t(61)=-2.22$, $p=0.030$, Cohen's $d=0.57$ (see **Figure 2F**).
225 As previously, the weights for food tastiness did not significantly differ between the *Health*
226 (M=0.11, STD=0.11) and the *Taste* group (M=0.10, STD=0.11), $t(61)=0.10$, $p=0.92$,
227 Cohen's $d=0.03$ (see **Figure 3E-F**).

228 As in Study 2, participants performed the online supermarket task following the food
229 rating task. We again found a positive and significant correlation between individual weights
230 for food healthiness during the social influence phase and average objective health score
231 during the supermarket task (health 'star points'), $r(62)=0.44$, $p<.001$ (see **Figure 4B**). Further
232 and in line with our hypothesis, the *Health* group bought significantly healthier food items on
233 average (i.e., items with higher objective health scores) than the *Taste* group, $t(58)=2.43$,
234 $p=0.018$, Cohen's $d=0.61$ (see **Figure 4D**). This suggests that the generalization of social
235 influence effects on food choices transferred to a second, independent and more ecologically
236 valid task in Study 3.

237

238

Discussion

239 People's behavior is influenced by how other people behave. A well-established and
240 health-relevant example is eating behavior: Observation of other people's food choices
241 influences both the type and amount of food we eat (Higgs, 2015), and such social context
242 effects may translate into important effects on health and well-being in the long-term. Social
243 influence is typically shown for specific observations of behavior (e.g., choosing specific food
244 items). Less is known on how humans infer more general social norms and how this influences
245 their behavior. Here, we tested the idea that social influence may generalize based on inferred
246 conceptual dimensions. More specifically, we studied whether the effects of other people's
247 food ratings can generalize based on two common conceptual attributes of food items:
248 tastiness and healthiness. In line with our hypothesis, the results of three different experiments
249 consistently showed such conceptual generalization of social influence, namely a change in
250 how people's food preferences were driven by health aspects. In other words, by observation

251 how peers rated different food items, participants inferred how much importance their peers
252 assigned to food healthiness. This inferred importance of the healthiness of the food item for
253 others then influenced participants' subsequent food preferences, leading to a higher or lower
254 preference for healthy food items. We did not observe a significant change in how people
255 weighted tastiness of foods and were only partially successful in extending this social
256 generalization of health weighting to an independent online supermarket food choice task
257 (discussed further below). Taken together, these findings suggest that people implicitly infer
258 the more general social norms driving other people's opinions and adjust their own
259 preferences accordingly—at least for knowledge-related conceptual attributes such as
260 healthiness, but not for more subjective attributes such as tastiness of foods.

261 These findings build on and further inform recent frameworks of how humans learn,
262 generalize, and represent conceptual relationships (Behrens et al., 2018; Constantinescu et
263 al., 2016; Dunsmoor & Murphy, 2015; Koban et al., 2021). A long history of work has
264 investigated the generalization of conditioned cue-stimulus association along perceptual
265 similarity gradients (Guttman & Kalish, 1956; Shepard, 1987) and perceptual generalization
266 also guides social decision-making (FeldmanHall et al., 2018; FeldmanHall & Dunsmoor,
267 2019; van Baar et al., 2021). Moreover, humans also generalize learned associations based
268 on conceptual relationships (Dunsmoor & Murphy, 2015; Tenenbaum & Griffiths, 2001). For
269 instance, humans also use categories and abstract representations to generalize learnt fear
270 responses (Dunsmoor & Murphy, 2015) and pain modulation (Koban et al., 2018). In the
271 context of food choices, a recent study has used an evaluative conditioning paradigm to show
272 that pairing a few unhealthy food items with unpleasant words or pictures leads to a lower
273 preference for other unhealthy compared to healthy food items (Bui & Fazio, 2016).

274 Our results suggest that such conceptual learning and inference processes could also
275 be at play during social interactions and social influence. They resonate with a study that used
276 social influence together with a hidden detection covariation design (Lewicki, 1986) to implicitly
277 shift attractiveness ratings of faces based on one perceptual features of the rated images
278 (namely hair length) (Ivanchei et al., 2019). Recent work has also used computational learning
279 models to understand how people infer other agents' mental states (e.g., beliefs and desires)
280 based on their observable actions (Baker et al., 2017; Jara-Ettinger, 2019). For instance,
281 theory of mind problems could be described with inverse reinforcement learning models, which
282 allow to recover latent world models and reward functions given observed policy execution
283 (Jara-Ettinger, 2019). In the present study, in which ratings of others were observed for
284 different food items, a possible underlying cognitive mechanism is the identification of the
285 latent reward function (or higher-order social norms) that best explain the variability in social
286 ratings. Identifying the higher-order social norms and reward functions that drive other

287 people's decision-making then allows the observer to be influenced by them and to not only
288 conform to specific behaviors but to social norms more globally.

289 This perspective also aligns well with recent findings and models in neuroscience.
290 Several studies have suggested that humans use grid-like code to navigate not only spatial,
291 but also perceptual and conceptual relationships between objects, allowing them to make
292 decisions about situations and object that they have never encountered in the same
293 configuration before (Constantinescu et al., 2016). Grid-like fMRI activity has been observed
294 in hippocampal and parahippocampal areas (Doeller et al., 2010), as well as ventromedial
295 prefrontal cortex (vmPFC) (Constantinescu et al., 2016; Park et al., 2020, 2021; Schafer &
296 Schiller, 2018) known to be involved in abstract cognition, memory, and spatial orientation.
297 VmPFC in particular has been suggested to guide behavior and decision-making by extracting
298 abstract situational features and conceptual models (Koban et al., 2021; Schuck et al., 2016)
299 and has also been associated with social and non-social reward processing (Hiser & Koenigs,
300 2018; Smith & Delgado, 2015), modulation of valuation by health-concerns (Hare et al., 2011;
301 Schmidt et al., 2018), and by social influence on food preferences (Nook & Zaki, 2015). The
302 vmPFC would thus be a candidate region for mediating conceptual generalization processes,
303 including generalization of social normative influence. Future studies could use brain imaging
304 to test these hypotheses.

305 While social influence generalized based on the importance of healthiness of food
306 items in all three experiments, no significant difference between the two groups was found for
307 the importance given to tastiness. Several reasons may explain this absence of effect for taste
308 weighting. First, how tastiness of food items is more idiosyncratic than perception of
309 healthiness (Puputti et al., 2019). It may therefore have been more difficult for participants to
310 accurately detect the social weighting of tastiness, therefore limiting is possible generalization.
311 However, previous evidence also suggests that importance of healthiness is more easily
312 modifiable than weighting of tastiness. For example, studies with different social norm
313 interventions have failed to find an impact on taste but shown it for health (Garcia, Hammami,
314 et al., 2021; Marty et al., 2018; Mollen et al., 2013). While taste preferences are difficult to
315 change, there are many studies showings social modeling of healthy food choices is a robust
316 phenomenon in different contexts (Ammerman et al., 2002; Higgs et al., 2019; Li et al., 2016;
317 Robinson et al., 2013, 2014; Thomas et al., 2017).

318 This is consistent with a recent meta-analysis (Melnyk et al., 2021) showing that social
319 norms have an especially large effect on socially responsible behavior in general. Purely
320 tastiness-driven eating is not perceived as a positive social norm which could explain why
321 participants were less influenced by taste-related norms (Higgs et al., 2019). The timing of
322 taste and health perception might also contribute to this difference. On average, people
323 estimate a food's tastiness more than 450ms before its healthiness (Sullivan & Huettel, 2021).

324 Together, these findings are in line with the idea that health considerations are a more
325 controlled, 'top-down' process, which may be more readily modulated by social norms than
326 more bottom-up appetitive processes such as food preferences based on tastiness.

327 In the last two studies, we also tested whether generalization of social influence in our
328 experimental task could transfer to an ecological online supermarket task. Our results in
329 Study 3, but not in Study 2, showed such a transfer, by demonstrating healthier food choices
330 in the online supermarket by participants in the Health-norm compared to participants in the
331 Taste-norm group. These findings build on other recent studies that have shown transfer of
332 learned strategies to regulate food craving across different food images and to real-life eating
333 behavior (Boswell et al., 2018). Other studies have also found maintenance over time directly
334 after the experiment (Higgs et al., 2019; Thomas et al., 2017) or five months after (Garcia,
335 Higgs, et al., 2021). However, Study 2 did not show a significant group difference in the
336 supermarket task and showed smaller effect size for the main social influence task as well.
337 Several differences between Studies 2 and 3 may explain this absence of effect. Study 2 was
338 conducted online in France and assessed food preference ('would like to eat') ratings, while
339 Study 3 was conducted in the laboratory in Germany and measured non-hypothetical
340 willingness-to-pay (WTP) for food items. The incentive compatible measure of WTP and the
341 more interactive and more controlled lab setting likely lead to higher engagement in the task
342 and may also increase sensitivity to social norms. Further, differences between participant
343 populations (Paris, France versus Bonn, a smaller city in Germany) and food products shown
344 may also contribute to the different results. Demographic factors such as proportion of female
345 versus male participants, BMI, income, and education differed slightly between the two
346 studies. However, these factors were not correlated with the objective health score and are
347 thus unlikely to substantially alter the results.

348 We note several other limitations of our study. First, the study participants were
349 relatively young and highly educated adult population. Social influence, especially towards
350 healthy foods, may have a greater impact in this population (Higgs, 2015; Li et al., 2016),
351 potentially due to differences in beliefs and concerns about healthy diets (Wardle et al., 2004).
352 Future studies should test whether these effects are also observed in more representative
353 samples. Second, we used the health and taste ratings from large sample of different
354 participants in order to not evoke these two dimensions prior to our experimental manipulation
355 and to reduce the time spent in the online surveys. This may have reduced the size of the
356 generalization effects, due to idiosyncratic differences in health and taste perception. Future
357 studies could acquire participant's idiosyncratic health and taste ratings to obtain better
358 representations of this two-dimensional conceptual space.

359 In conclusion, the results of our three studies showed that people infer social norms
360 regarding the importance of healthiness when observing other people's food ratings and these

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361 implicit norms shift their own food preferences. Taste might be less susceptible to social
362 influence due to idiosyncratic perceptions of tastiness and more automatic processing of taste,
363 compared to health attributes. Future studies could test generalization of social influence
364 effects in other domains and characterize the brain mechanisms underlying these effects.
365 Given that social norms are one of the most efficient ways to change behavior and decision-
366 making (Zhao et al., 2022), better understanding how social norms are inferred and how social
367 influence can generalize across different instances and contexts opens new possibilities for
368 interventions to encourage healthier eating and other health-related behaviors in everyday life.
369 More broadly, our findings suggest a new mechanism of how human behavior can be
370 influenced by unspoken social norms even in new instances, thus providing new insight in how
371 human learn about and adapt to group norms and culture.

372

Methods

373

374 **Participants**

375 **Study 1.** We recruited 198 adult volunteers for Study 1, using an online participant
376 pool in Germany (ClickWorker). The data of two participants were excluded due to no variance
377 in ratings, leaving a final sample of 196 participants (73 females and 123 males, mean age=
378 36 years, range 18-60 years), 97 in the *Health* group and 99 in the *Taste* group. The groups
379 were matched for age, BMI, sex ratio, education, and income level (all p-values > 0.37, see
380 Supplementary Table S1).

381 **Study 2.** We recruited 206 adult volunteers for Study 2, using an online participant
382 pool in Paris, France from the INSEAD-Sorbonne University behavioral laboratory. The data
383 from one participant was excluded from all analyses because data for the supermarket task
384 was not registered, leaving a final sample of 205 participants (140 females and 65 males, 103
385 in *Health* group and 102 in *Taste* group, mean age=24.5 years, range 18-35 years). The
386 groups had comparable age, BMI, sex ratio, education, and income level (all p's < 0.34, see
387 Supplementary Table S1).

388 **Study 3.** We recruited 66 adult volunteers for Study 3 from the participant pool of the
389 BonnEconLab at the University of Bonn, Germany. Data from two participants was excluded
390 from all analyses because the results for the supermarket task were not recorded, leaving a
391 final sample of 64 participants (30 females and 34 males, 32 in *Health* group and 32 in *Taste*
392 group, mean age= 24 years, range 18-35 years). The two groups were matched for age, BMI,
393 and sex ratio, education, and income level (all p's>0.57, see Table Supplementary S1).

394 In all three studies, participants provided informed consent and were paid for their time.
395 The studies were conducted according to the Declaration of Helsinki and approved by the
396 institutional review board of INSEAD (Studies 1-2) and Bonn University (Study 3).

397

398 **Experimental design**

399 During the first 16 trials of the food rating task (baseline phase), all participants rated
400 the same 16 food items (presented in randomized order) without any social information,
401 allowing us to control for participants' habitual weighting of health and taste considerations.
402 Then, during the social influence phase (80 trials in Studies 1 and 3, 64 trials in Study 2),
403 participants were presented with the ratings of several other participants following their own
404 rating.

405 Participants were randomly assigned to one of two experimental groups using a
406 pseudo-random number generator of Qualtrics. In the *Health* group, healthier but less tasty
407 food items were associated with higher average preference ratings of others, whereas
408 unhealthy but tasty items were associated with lower social ratings. In the *Taste* group, tastier

409 but less healthy food items received higher preference ratings from others than healthier and
 410 less tasty items (see also Fig. 1B). See below for more details on the selection of social ratings
 411 for the different food stimuli.

412

413 **Stimuli and materials**

414 **Food items.** In each of the three studies, participants were presented with photos of
 415 80 different snack food items, such as chips, nuts, fruits, and chocolate bars. All items were
 416 shown on a black background and selected from INSEAD's standardized picture databases
 417 (adapted from Schmidt et al., 2018) of German (in Study 1 and 3) or French supermarket
 418 products (in Study 2). Each item i had been previously rated by independent online participants
 419 ($N=105$ for the German food database, $N=298$ for the French food database) for its healthiness
 420 ($health_i$), 'How healthy is this product?', tastiness ($taste_i$), 'How tasty is this product?',
 421 willingness to pay (WTP) 'How much are you willing to pay for this product?' and familiarity
 422 ('How familiar are you with this product?'). The $health_i$ and $taste_i$ in $SocValue(i)$ were based on
 423 these health and taste ratings. Food cues were selected to systematically vary in healthiness
 424 and tastiness. Further, we divided the 80 food stimuli into five sets of 16 stimuli, such that each
 425 set contained four items rated high tastiness and low in healthiness, four items high in
 426 tastiness and high in healthiness, four items low in tastiness and low in healthiness, and four
 427 items low in tastiness and high in healthiness, with each of this four ad-hoc categories being
 428 matched for familiarity, and such that each set of 16 times was matched for average
 429 healthiness, tastiness, and familiarity. This allowed us to present the five matched sets in
 430 random order and to investigate the time course of social generalization effects.

431 **Social ratings.** During the social influence phase, we presented the ratings of ten
 432 (Studies 1-2) or seven (Study 3) previous people after participants had submitted their own
 433 rating. The social ratings were displayed as small circles on a visual analog scale that matched
 434 the VAS that participants used for their own ratings (see **Figure 1A**). They were simulated
 435 (Studies 1-2) or selected (Study 3) as a function of the taste and health attributes of each food
 436 items. More specifically, for each food item i and each experimental condition, we used the
 437 following equation to simulate a mean social value (SV) for each food item i :

438

$$439 \quad SV(i) = \beta_{s_0} + \beta_{s_H} health_i + \beta_{s_T} taste_i$$

440

441 Where β_{s_0} reflects a fixed intercept ($\beta_{s_0}=20$ in Studies 1-2, $\beta_{s_0}=1.2$, to avoid values below 0),
 442 β_{s_H} reflects the weighting of health in the social ratings, and β_{s_T} reflects the taste weighting in
 443 the social ratings, with $health_i$ describing the healthiness and $taste_i$ the tastiness of each food
 444 item. Social weighting of health and taste differed between the two experimental groups in

445 order to create two different social influence conditions. In the *Health* group, health had a high
446 weight ($\beta_{SH}=0.8$ in Studies 1-2, $\beta_{SH}=0.7$ in Study 3) and taste had a low weight ($\beta_{ST}=-0.2$ in
447 Studies 1-2, $\beta_{ST}=0.2$ in Study 3). The opposite was the case for *Taste* group ($\beta_{SH}=-0.2$ and
448 $\beta_{ST}=0.8$ in Studies 1-2, $\beta_{SH}=0.2$ and $\beta_{ST}=0.7$ in Study 3).

449 For Studies 1-2, in order to create ten different ratings (to reflect the ratings of ten other
450 individuals) for each food item and each condition, we used Matlab 2018b to generate
451 Gaussian distributions with $SV(i)$ as the mean and a standard deviation of 15, from which we
452 drew a random set of ten social ratings. For Study 3, we chose the seven WTP ratings in the
453 INSEAD food database of German supermarket products that were closest to the simulated
454 ratings. This approach added some variation around the simulated mean social values, thus
455 leading to realistic and plausible values, as previous results have shown that people's food
456 choices and brain valuation signals can be modeled based on taste, health, and other
457 attributes (Maier et al., 2015; Rangel, 2013; Schmidt et al., 2018).

458

459 **Procedures**

460 Studies 1-2 were conducted online and launched in the late afternoon to early evening.
461 In Study 3, participants performed the tasks on computers in individual cubicles of the
462 BonnEconLab, at the same time as several other participants in the late afternoon. This timing
463 ensured that participants were moderately hungry (see Supplementary Table S1) and likely
464 interested in the snack food items presented.

465 The food rating task, administered via Qualtrics, consisted of 96 trials (in Study 1 and
466 3) or 80 trials (Study 2) that were composed of several blocks of 16 trials each (**Figure 1A**).
467 The first block constituted a baseline, in which participants were presented 16 different food
468 items and rated how much they would like to eat the shown item at this moment ("How much
469 would you like to eat this?", Study 1-2, see below) or how much they are willing to pay for this
470 item (WTP, Study 3, see below), without any social ratings presented. This baseline block
471 allowed us to verify that there were no group differences in food preferences before the social
472 influence manipulation. The subsequent social influence phase was composed of five (Study
473 1 and 3) or four (Study 2) continuous blocks (see **Figure 1**). During the social influence phase,
474 participants first rated the food item and were then presented (for at least 3s and until they
475 continued per mouse click) with what we told them were the ratings of several other people
476 for the same food item ('social ratings').

477 The first four blocks during the social influence phase (T1-T4) presented a total of 64
478 different food items (all different from each other and different from the items shown during
479 the baseline phase). The order of food items was randomized within blocks and the order of
480 blocks T1-T4 was counterbalanced across participants to obtain a similar composition of
481 health and taste features in each block. The 5th block (Studies 1 and 3 only) was composed

482 of the same 16 food items as during the baseline, allowing us to test the effects of social norm
483 learning on both unseen and previously rated food items. However, due to limited statistical
484 power, we do not compare bin-by-bin differences in our effects.

485 **Food preference ratings (Study 1-2).** In all trials of Studies 1 and 2, participants rated
486 the food items ('How much would you like to consume this product at this moment?') on a
487 visual analogue scale (VAS) from 0 (*not at all*) to 100 (*very much*) (self-paced and without time
488 limit), which was displayed underneath the photo of the food item. Ten social ratings were
489 subsequently presented on a similar VAS, again underneath the food picture (for at least 2s
490 and a maximum of 8s, if participants did not click to advance the survey).

491 **Willingness-to-pay (WTP) for food items (Study 3).** Study 3 assessed WTP as an
492 incentive-compatible measure of food craving. In each trial, participants indicated their WTP
493 on a slider scale from 0-3 Euro (in 10-cent increments), which was displayed below the food
494 item. WTP, as measured using a Becker-DeGroot-Mashak auction (Becker et al., 1964) is the
495 gold standard to measure subjective valuation in behavioral economics and less susceptible
496 to demand effects (Wertenbroch & Skiera, 2002). Participant were instructed as following:
497 'You will get an extra €3 for your participation in this study. During the experiment, you will be
498 allowed to use this money to buy a snack from us. In fact, we would like you to think of us as
499 your personal convenience store. Whatever money you do not spend is yours to keep and will
500 be transferred to your bank account upon completion of the study. For your bids, you will
501 receive €3, which you can either spend on your bid for one of the products or keep for yourself.
502 At the end of the experiment, one of your bids from a random subset of products will be
503 chosen. You do not have to worry about how you want to spread your budget on the different
504 products, as only one bid will count. That means you can spend up to €3 for each product if
505 you want.' As instructed, a random trial was selected at the end of the experiments and a price
506 between 0-3 Euro was randomly generated by a computer algorithm. If the bid was as high or
507 higher than the price generated by the computer, the participant had to pay the price and
508 received the food item, otherwise they did not have to pay and did not receive any food item.
509 After the WTP rating, participants were presented with the WTP of previous participants, again
510 shown on the same scale below the picture of the food item (for at least 2s and a maximum of
511 8s, if participants did not click to advance the survey).

512 **Supermarket task.** In Studies 2 and 3, participants performed an online supermarket
513 task following the food choice task. We used Howe's Grocery (<https://openscience-onlinegrocery.com/>), an online supermarket developed for research purposes (Howe et al.,
514 2022) which allows to investigate food decision-making in a naturalistic setting very similar to
515 many real online grocery shops (Fig. 1D). Participants were asked to select several food items
516 in the online supermarket with the following instructions: 'Imagine that you move to the US for
517 a 3-month internship. When you arrive in your apartment you need to get some groceries for
518

519 tomorrow's breakfast and some snacks for the day. Buy what you would like from the online
 520 supermarket below. Keep in mind that in total, you should spend any amount between 40-60
 521 US Dollar.'. The participants were aware that this was a hypothetical purchasing task and that
 522 they would not pay for or receive any food ordered in Howe's Grocery Store.

523 **Other measures.** Before and after the task, participants rated how hungry they felt
 524 (see Supplementary Table S1). They provided basic demographic measures, self-reported
 525 height and weight (allowing us to compute their body mass index / BMI), as well as general
 526 dietary habits using custom items. In total, participation in the study took approximately 30-
 527 45 minutes.

528

529 **Statistical analysis**

530 **Food rating task.** Participants' individual health (β_H) and taste beta weights (β_T) were
 531 computed by fitting a multilevel general linear model (GLM) to participants' food wanting
 532 ratings (Studies 1-2) or WTP (Study 3) $V(i)$ as a function of the healthiness and tastiness of
 533 each food item I , separately for the baseline and the social influence phase:

534

$$535 \quad V(i) = \beta_0 + \beta_H \text{health}_i + \beta_T \text{taste}_i$$

536

537 For statistical analyses of group differences, we performed a GLM to test the effect of
 538 group on individual health and taste weights (β_H and β_T) during the social influence phase (see
 539 Fig. 2B), controlling for baseline weights. All statistical tests used a significance threshold of p
 540 < 0.05 (two-sided). Shapiro-Wilk normality test was used to examine the normality distribution
 541 of each variable. Data were analyzed using Matlab version R2020b, R version 3.6.1 (R Core
 542 Team, 2020), and RStudio version 1.2.5001.

543 **Supermarket task.** We analyzed the healthiness of products selected in the
 544 participants' shopping basket at check-out, by computing the average health star points of all
 545 the food items in participants' online basket at the time of check-out ('health star points').
 546 Howe's Grocery store includes detailed information regarding the nutritional composition of
 547 each food item, including calories, fat, carbohydrates, fiber, sugar, protein, and other
 548 measures. Based on its nutritional composition, each food is associated with an aggregate
 549 health measure, the so-called 'health star points'. The health star points ranged from minus
 550 ten to ten, with greater values indicating more healthiness (see details in Howe et al., 2022).
 551 Food items high in vitamins, minerals, fiber, whole grains, and omega-3 have higher number
 552 of health star points, whereas foods with saturated and trans fatty acids, added sodium, added
 553 sugar and artificial colors have a lower number of health star points.

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556 **Code and data availability**

557 Code for analysis is available at <https://github.com/ldmk> and <https://github.com/canlab>.

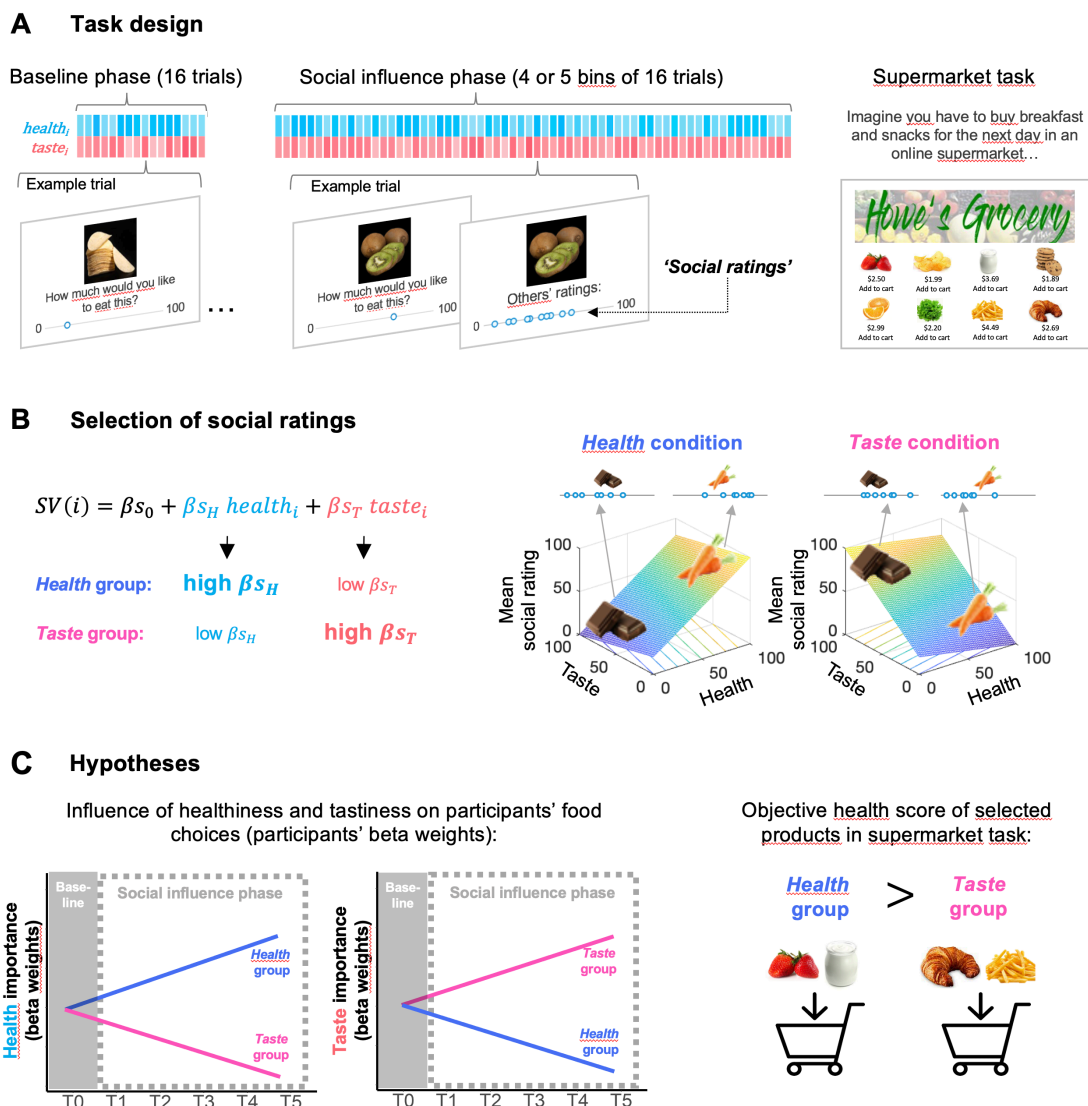
558 Deidentified aggregate data will be made available (<https://github.com/ldmk>) before
559 publication of the manuscript.

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Figures

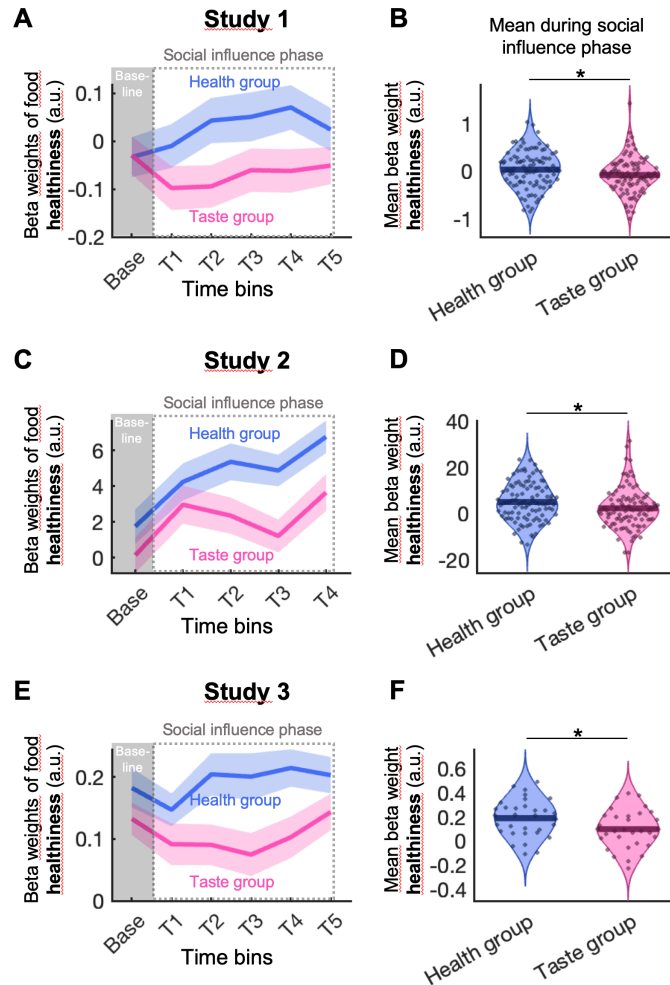


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566 **Figure 1. Experimental design and hypotheses.** A) **Task design.** During the food choice
567 task (left and middle), participants had to rate different food items, which varied on healthiness
568 and tastiness ($health_i$ and $taste_i$) as rated by an independent sample of participants. Brighter
569 versus darker colored bars illustrate less to more healthy (light to darker blue) and less versus
570 more tasty (light to darker red) food items (randomized across participants). During the
571 baseline phase (left), participants were presented with 16 food items in total without receiving
572 any social feedback. During the social influence phase, participants were presented with 64-
573 80 food items. For each food item, they rated how much they would like to eat it and were then
574 presented with what we told them were the ratings of several other individuals. In Studies 2-3
575 and following the food rating task, participants performed a naturalistic online supermarket
576 task. They were instructed to select several foods and drinks, as if they had to buy groceries

577 for next days' breakfast and snacks. **B) Selection of social ratings in the two experimental**
578 **conditions in all three studies.** Participants were randomly assigned to one of two
579 experimental conditions of the food rating task. In the *health group*, the mean social value (SV)
580 of each food item *i* was computed with a high beta weight for the item's healthiness (*health_i*)
581 and a low weight for its tastiness (*taste_i*). In contrast, in the *taste group*, the mean social value
582 (SV) of each food item *i* was computed with a high beta weight for the item's tastiness (*taste_i*)
583 and a low weight for its healthiness (*health_i*). Several ratings were randomly drawn from a
584 distribution around the mean SV to ensure plausible and variable social ratings. Thus, as
585 illustrated on the right side, in the health group, healthy items such as vegetables or fruit would
586 be followed by relatively high ratings, whereas unhealthy but tasty items such as chocolates
587 or sweets would be followed by relatively low ratings. In the taste group, this relationship was
588 the other way around. **C) Hypotheses.** We expected that participants in the health group
589 would over time increase how much healthiness of food items influenced their food ratings as
590 influenced by increased beta weights for *health_i*, whereas participants in the taste group would
591 show lower influence of health considerations in their choices during the social influence
592 phase. The opposite pattern was expected for the influence of taste on food ratings (beta
593 weights of *taste_i*). We further expected that this effect would transfer to a second, independent
594 supermarket task, such that participants in the health group would select healthier food items
595 (as measured by a higher objective health star point score) than participants in the taste group.
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602 **Figure 2. Influence of food healthiness on participants' ratings. A) Study 1.** Time course

603 (per 16 trial bins) of beta weights of healthiness on food ratings in the health group (in blue)

604 and the taste group (in pink). **B) Group difference (Study 1).** Controlling for baseline values,

605 the Health group showed significantly higher health beta weights than the Taste group during

606 the social influence phase. **C) Study 2.** Time course (per 16 trial bins) of beta weights of

607 healthiness on food ratings in the health group (in blue) and the taste group (in pink). **B) Group**

608 **difference (Study 2).** Controlling for baseline values, the Health group showed significantly

609 higher health beta weights than the Taste group during the social influence phase. **E) Study 3.**

610 Time course (per 16 trial bins) of beta weights of healthiness on food ratings in the health

611 group (in blue) and the taste group (in pink). **F) Group difference (Study 3).** Controlling for

612 baseline values, the Health group showed significantly higher health beta weights than the

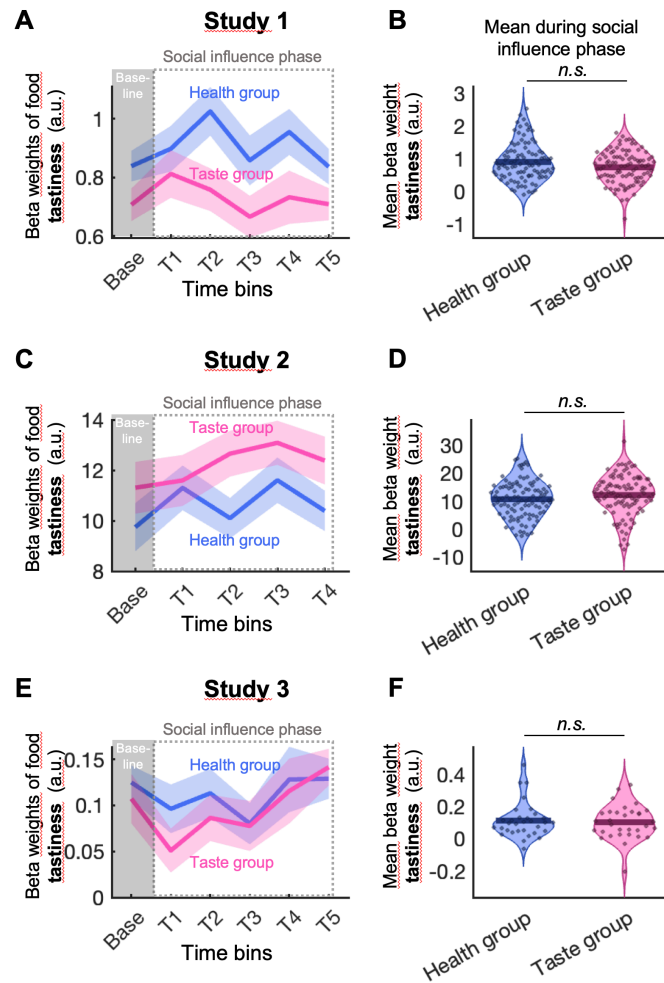
613 Taste group during the social influence phase. Asterisks (*) indicate a significant difference

614 between the two groups ($p < 0.05$). Violin plots show individual participants as dots and group

615 means as black lines. Pooled across all three studies, the average effect size for the group

616 difference in health weighting was Cohen's $d = 0.35$.

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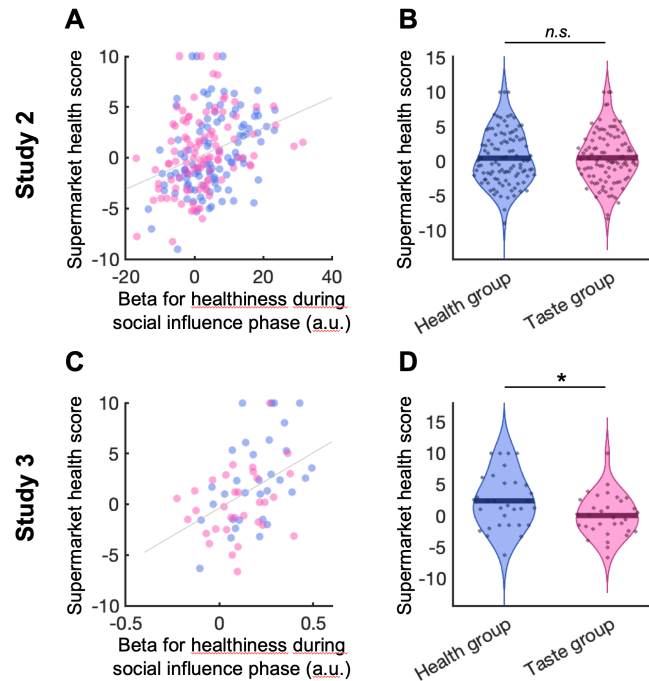
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620 **Figure 3. Influence of food tastiness on participants' ratings. A) Study 1.** Time course
 621 (per 16 trial bins) of beta weights of $taste_i$ on food ratings in the health group (in blue) and the
 622 taste group (in pink). **B) Group difference (Study 1).** Controlling for baseline values, there
 623 were no significant differences in $taste_i$ between groups. **C) Study 2.** Time course (per 16 trial
 624 bins) of beta weights of $taste_i$ on food ratings in the health group (in blue) and the taste group
 625 (in pink). **D) Group difference (Study 2).** Controlling for baseline values, there were no
 626 significant differences in $taste_i$ between groups. **E) Study 3.** Time course (per 16 trial bins) of
 627 beta weights of $taste_i$ on food ratings in the health group (in blue) and the taste group (in pink).
 628 **F) Group difference (Study 3).** Controlling for baseline values, there were no significant
 629 differences in $taste_i$ between groups. Violin plots show individual participants as dots and
 630 group means as black lines. *n.s.* = not significant.

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635 **Figure 4. Results of the supermarket task (Studies 2 and 3).** **A)** and **C)** In both Studies 2
 636 and 3, the healthiness of food choices in the supermarket task was positively correlated with
 637 the influence of *health*_i during the social influence phase of the food choice task (Study 2:
 638 $r(203)=0.34$, $p<.001$; Study 3: $r(62)=0.44$, $p<.001$). **B)** In Study 2, no significant difference in
 639 supermarket health score was found between groups. **D)** In Study 3, in line with our
 640 hypothesis, participants in the health group chose healthier products in the supermarket task
 641 than participants in the Taste group ($t(58)=2.43$, $p=0.018$, Cohen's $d=0.61$).

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Supplementary materials

Social influence effects on food valuation generalize based on conceptual similarity

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Supplementary Table S1.*Demographic variables and hunger ratings by experimental group in Studies 1-3.*

Study	Health group		Taste group		t-value	df	p-value
	Mean	SD	Mean	SD			
Age (years)							
Study 1	35.4	9.32	36.7	9.16	-0.90	193	0.37
Study 2	24.4	3.17	24.6	3.90	-0.33	193	0.74
Study 3	23.7	3.62	24.3	4.21	-0.57	61	0.58
BMI (kg/m²)							
Study 1	25.0	4.80	24.6	4.56	0.65	194	0.52
Study 2	22.5	4.38	22.7	3.84	-0.33	200	0.74
Study 3	23.7	3.47	23.8	3.63	-0.11	62	0.91
Pre-task hunger (from 0 to 100)							
Study 1	45.00	26.88	50.38	28.45	-1.36	194	0.17
Study 2	48.94	30.23	49.97	30.01	-0.24	203	0.80
Study 3	55.34	23.72	62.90	22.95	-1.15	62	0.25
Post-task hunger (from 0 to 100)							
Study 1	52.99	27.77	58.11	28.96	-1.26	194	0.20
Study 2	56.00	28.17	63.47	24.85	-2.01	200	0.05
Study 3	62.03	25.26	72.25	16.99	-1.90	54	0.06
Annual income (in Euro)					rank sum		
Study 1	33838	27464	34076	23107	4502		0.45
Study 2	12817	11466	12699	13281	5950		0.61
Study 3	9518	9784	9661	9413	512		1
Higher education (years)							
Study 1	1.69	1.85	1.82	1.76	4736		0.90
Study 2	4.17	1.55	3.89	1.59	5948		0.08
Study 3	1.31	0.64	1.78	1.16	402		0.08
Gender (Female/Male)					χ²		
Study 1	39 / 58		34 / 65		0.49	1	0.48
Study 2	74 / 29		66 / 36		0.90	1	0.34
Study 3	15 / 17		15 / 17		0	1	1

Note. Df=degree of freedom, SD=Standard Deviation. Welch's *t*-tests were performed for age, BMI, and hunger. Chi-square tests were performed for gender ratio and Wilcoxon-Mann-Whitney test for income and education.