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## The impact of 16-h heat exposure on appetite and food reward in adults

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25 **Abstract** <sup>1</sup>

26

27 Heat exposure is thought to reduce energy intake (EI) but studies are sparse and results not  
28 always concordant. The aim of this study was to examine whether a 16-h exposure to 32°C leads  
29 to reduced EI compared to a control session (22°C) and whether modifications in appetite  
30 sensations or food reward are implied. Sixteen healthy, lean, and active participants (9 women  
31 and 7 men, 25±5 yo, body mass index: 22.0±2.4 kg.m<sup>-2</sup>) were passively exposed to two different  
32 thermal temperatures from 4:00 pm to 8:00 am under controlled conditions. Hunger and thirst  
33 scores were regularly assessed using visual analogue scales. A fixed dinner meal (3670±255 kJ)  
34 was consumed at 7:30 pm and an ad libitum breakfast buffet (20 foods/drinks varying in  
35 temperature, fat, and carbohydrate content) at 7:30 am. Components of reward (explicit liking  
36 [EL] and implicit wanting [EI]) for fat and sweet properties of food were assessed before each  
37 meal using the Leeds Food Preference Questionnaire (LFPQ). *Ad libitum* EI at breakfast did not  
38 differ between sessions (2319±1108 vs 2329±1141 kJ, in 22 and 32°C sessions, respectively;  
39  $p=0.955$ ). While thirst scores were higher in the 32 than the 22°C session ( $p<0.001$ ), hunger  
40 scores did not differ ( $p=0.580$ ). EL and IW for high fat foods relative to low fat foods were  
41 decreased in 32 compared to 22°C before dinner and breakfast ( $p<0.001$  for all). Although EI and  
42 hunger were not affected by a 16-h exposure to heat, modifications in food reward suggested a  
43 reduction in the preference of high-fat foods. Future research should investigate whether  
44 reduced EI in response to heat exposure is due to spontaneous selection of low-fat foods rather  
45 than altered appetite sensations.

46

47 **Keywords:** LFPQ, hot conditions, thermal exposure, appetite, energy balance, hunger

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**Abbreviations**

CAS: composite appetite score

EB : energy balance

EE: energy expenditure

EI: energy intake

EL: explicit liking

IW: implicit wanting

LFPQ : Leeds Food Preference Questionnaire

RH: relative humidity

VAS: visual analogue scale

## 48 1. Introduction

49 Athletes and military personnel are regularly exposed to energy deficits due to inadequate levels  
50 of energy intake (EI) compared to their high levels of energy expenditure (EE) (Charlot, 2021;  
51 Heydenreich, Kayser, Schutz, & Melzer, 2017; Logue et al., 2020; Tassone & Baker, 2017; Tharion  
52 et al., 2005). If sustained, this state may have direct deleterious consequences on their cognitive  
53 (Giles et al., 2019; O'Leary, Wardle, & Greeves, 2020) and physical (Murphy, Carrigan, Philip  
54 Karl, Pasiakos, & Margolis, 2018; O'Leary et al., 2020) performances. Seasonal scheduling and  
55 localization of competitions may impose athletes to train/compete in the heat during a  
56 significant duration (de Korte, Bongers, Hopman, & Eijsvogels, 2021; Racinais, Casa, Brocherie, &  
57 Ihsan, 2019). For their part, militaries are often deployed in war zones characterized by a hot  
58 climate (Ashworth, Cotter, & Kilding, 2020; Parsons, Stacey, & Woods, 2019). During acute heat  
59 exposures (< than 8 h), EI was found to be reduced in some studies compared to a  
60 thermoneutral control session (Shorten, Wallman, & Guelfi, 2009; Wasse, King, Stensel, &  
61 Sunderland, 2013; Zakrzewski-Fruer, Horsfall, Cottrill, & Hough, 2021). Given that EE is  
62 unaltered or even slightly increased due to an rise in ventilation and sweat gland activity in this  
63 thermal environment (Ocobock, 2016; Valencia, McNeill, Brockway, & Smith, 1992), energy  
64 balance (EB; EI *minus* EE) is very likely to be negative during heat exposures. These decreases  
65 were sometimes accompanied by reductions in appetite (assessment of hunger scores) (Kojima,  
66 Sasaki, Tsuchiya, & Goto, 2015; Wasse et al., 2013) and increases in the plasma levels of  
67 anorexigenic hormones such as peptide YY (Shorten et al., 2009; Zakrzewski-Fruer et al., 2021).  
68 These results imply that heat exposures may potentially worsen the already frequent and large  
69 states of energy deficiency.

70 To date, these effects remain uncertain since the literature is sparse and some studies have  
71 reported no modifications in appetitive responses (Ahmed et al., 2019; Faure et al., 2016). The  
72 main reason for this lack of consistency is very likely the considerable variability of the protocols  
73 (duration of exposure, choice of temperature, presence of physical exercise sessions, test meals,  
74 clothing...) (Charlot, Faure, & Antoine-Jonville, 2017; Millet et al., 2021). Although a recent meta-  
75 analysis found a slight heat-induced anorexia (Millet et al., 2021), further studies are required to  
76 help draw more solid conclusions on the effects of heat exposure on appetite and EI. Particularly,  
77 studies in which heat exposure is applied during a prolonged period (> 8 h) and during  
78 sedentary conditions are required in order to eliminate the biases induced by physical exercise.  
79 Food reward has been shown to strongly influence food choices and EI in both laboratory and  
80 free-living settings (Dalton & Finlayson, 2014; French et al., 2014). However, food reward is  
81 rarely assessed in extreme environments (Charlot et al., 2021; Karl et al., 2018) and never to our  
82 knowledge during heat exposure. The construct of food reward and its sub-components of liking  
83 and wanting may help elucidate the heat-induced anorexia that is often observed.

84 The aim of this study was therefore to assess the effects of 16-h passive heat exposure on EI  
85 assessed during an *ad libitum* breakfast and associated changes in appetite and food reward. It  
86 was hypothesized that heat exposure would exert an anorexigenic effect reflected by a decrease  
87 in hunger scores, and/or a decrease in liking and wanting for high fat foods, both resulting in  
88 lower EI.

89

## 90 **2. Materials and methods**

### 91 **2.1. Design**

92 Participants took part in four 16-h sessions separated by ~2 weeks in a climatic apartment (four  
93 bedrooms, a living-room with a kitchen and a bathroom with a shower and a toilet) in which  
94 ambient temperature was fixed at 22 or 32 °C (two sessions in each temperature). The measured  
95 ambient temperatures were  $22.5 \pm 0.7$  °C and  $32.3 \pm 0.6$  °C, respectively. Relative humidity was  
96 fixed at  $\sim 40 \pm 5\%$ . Four groups of 4 participants were composed and this composition remained  
97 similar during the study. The session order was randomly allocated and counterbalanced for the  
98 4 groups. Just before 4:00 pm, participants arrived and were fitted with devices for continuous  
99 measurements of heart rate, skin temperature, and ingestion of a thermal pill. Dressed in  
100 standardized clothes (short sleeves tee-shirt made of cotton, shorts made of polyester, socks  
101 made of cotton, and synthetic sandals), the participants remained in the apartment until the next  
102 morning (8:30 am). At 7:30pm, a dinner (pasta, yoghurt, and chocolate bar) served in  
103 standardized quantity was consumed. At 9:30pm, they went to bed and were woken up at  
104 7:00am. At 7:30 am, an *ad libitum* breakfast buffet was served with a large selection of foods and  
105 drinks. Breakfast EI was calculated from the weighed quantity consumed. Food reward using the  
106 LFPQ was assessed just before the dinner and the breakfast. Subjective appetite and thermal  
107 sensations were assessed throughout the sessions using visual analog scale (VAS). Fluid and  
108 food intake and fluid loss (urine and sweat) were directly measured or calculated during the  
109 sessions. The first session at each temperature was treated as a familiarization session. The  
110 second session at each thermal condition was treated for analysis (~1 month apart). The  
111 procedure is presented in Figure 1.

112

### 113 **2.2. Participants**

114 Sixteen healthy, young, lean, and active participants (9 women and 7 men) were recruited from  
115 the Institut de Recherche Biomédicale des Armées (age:  $25 \pm 5$  yo; body mass:  $64.6 \pm 9.5$  kg,  
116 height:  $171 \pm 7$  cm, and body mass index:  $22.0 \pm 2.4$  kg.m<sup>-2</sup>). Inclusion criteria were restraint  
117 score < 2 based on the Three-Factor Eating Questionnaire-R18 (Karlsson, Persson, Sjöström, &  
118 Sullivan, 2000), regularly consuming at least 3 meals per day including breakfast, and have a  
119 sleep score < 5 based on the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, &

120 Kupfer, 1989). They were also not eligible if they had been exposed to a hot climate (> 3  
121 consecutive days, mean temperature > 30 °C) in the last 6 months before the study to ensure  
122 that participants were not considered heat acclimated. Given that this study was realized in  
123 spring 2021, they were not exposed to temperature above 20 °C in the 6 previous months.  
124 Female participants who used contraceptive medication and had irregular menstrual cycle  
125 (absence of regular cycle for at least 3 consecutive months) were excluded. Female participants  
126 had to realize the two sessions that were considered for analysis at the same phase of their  
127 menstrual cycle since core temperature regulation (Baker, Sibozza, & Fuller, 2020), appetite and  
128 EI (Asarian & Geary, 2013) fluctuated during the menstrual cycle higher. The second session was  
129 therefore planned approximately 30 days ( $29 \pm 4$  d) after the first one. This study was conducted  
130 according to the guidelines laid down in the Declaration of Helsinki and all procedures were  
131 approved by the French National Ethics Committee Sud Méditerranée n°2 (2021-A01238-33).  
132 Written informed consent was obtained from all participants who received financial  
133 remuneration for study completion.

134

### 135 **2.3. Measurements**

#### 136 *2.3.1. Energy intake*

137 Participants were asked to eat the same breakfast at the same hour (depending on their habits)  
138 before each session. Since all the participants worked on site, they were instructed to eat at the  
139 mess at the same hour (between 11:30am and 12:30pm) and eat the same kind of meals (one  
140 salad, one main dish with meat or fish and pasta or rice on the side, one portion of cheese, one  
141 yoghurt, and one fruit). They were also instructed to drink at least 5 glasses of water (~ 1 L) on  
142 this day to avoid disparities in the hydration level and to not perform physical activities on the  
143 day and day before the study.

144 Dinner was composed of a main dish (carbonara, salmon, cheese, or meat balls pasta, Grande  
145 Box, Lustucru®, ~360 g), a yoghurt (Vanilla, Chocolate, Lemon, or Coconut Yoghourt, Yaourt  
146 Gourmand, Mamie Nova®, 125 g) and a bar of milk chocolate (Milka®, 17 g). Participants chose  
147 the recipes/flavor of the first two items during a screening visit. During the first session, the full  
148 portions were served but participants could choose to not finish them knowing that the same  
149 quantities would be served during the remaining sessions with the obligation to finish them.  
150 Thus, food, quantities, and therefore EI was fixed during this meal. Two subjects chose to eat 2  
151 yoghurts and two others ate only half of the chocolate bar. Mean EI of the meal was  $3670 \pm 255$   
152 kJ with a CHO/Fat/Protein distribution of  $51 \pm 2\%$ ,  $37 \pm 2\%$ , and  $13 \pm 1\%$ .

153 A breakfast buffet was served ad libitum. It was composed of a selection of drinks, savory and  
154 sweet and/or high-fat and low-fat foods, and extras/toppings. The details are presented in Table  
155 1. The buffet was prepared outside the climatic apartment in a room at ~22°C. Some items were

156 served at room temperature (~ 22°C). Other were served cold (~ 4°C) and some were served hot  
157 (~ 50°C). Pre-tests revealed that the gustatory properties of some items were impaired after 20-  
158 30 min in a room at 32 °C. To avoid this deterioration, the buffet was set on two large tables in a  
159 temperate room (20-24 °C) outside the climatic apartment. These tables were then moved just  
160 before 7:30 am in order that participants may choose drinks and foods with similar gustatory  
161 properties in both thermal conditions. Each item was served in large quantities (see Table 1).  
162 Participants were informed that they were allowed to freely serve themselves and that they  
163 were not forced to finish their dish. They served themselves using specific cutlery and placed  
164 each item in specific disposable dishes (small plates, bowl, cup, or goblet). An investigator then  
165 weighed (Mettler Toledo, Columbus, OH, USA, accuracy: 0,1g) each dish with the served portion.  
166 The same dish with remaining foods and drinks were weighed after breakfast. The difference  
167 between before and after the breakfast corresponded to the consumed quantities. They were  
168 allowed to serve themselves three times in total. If available food portions decreased by  
169 approximately 50% of the starting portion, investigators refilled the concerned items to ensure  
170 that served portions were similar between participants. They were previously informed that  
171 food selection and EI were assessed since it was impossible to totally conceal the weighing  
172 procedure. This latter phase was however done the most quick and discrete possible: after they  
173 served themselves, they had to leave their tray on a table in the main room and returned to their  
174 respective room. The weighing lasted less than 30 seconds and their tray was then handed over  
175 to the participants. Finally, all the procedure (food selection and eating) was done entirely  
176 separately in order to avoid the well-known social facilitation of eating (Ruddock, Brunstrom,  
177 Vartanian, & Higgs, 2019). Before the beginning of the breakfast, participants remained in their  
178 room with their door shut. They were invited one at the time to serve themselves at the buffet  
179 and to eat alone in their room. The participants therefore never crossed during the whole  
180 breakfast.

181

182 **Table 1 – Composition of foods and drinks served in the *ad libitum* breakfast buffet**

Item	Brand	Served portion	Energy content (kJ/100 g)	CHO (g/ 100g)	Fat (g/100 g)	Protein (g/100 g)
<b>Drinks</b>						
Milk*	Auchan	1000 mL	196	4.8	1.6	3.3
Orange juice*	Tropicana	1000 mL	162	8.9	0.0	0.8
Grape juice*	Auchan	1000 mL	295	16	0.5	0.5
<b>Sweet foods</b>						
Applesauce*	Andros	1000 g	343	20.0	0.1	0.3
White cheese*	Auchan	1000 g	459	2.9	7.8	7.0
Corn flakes**	Kellog's	500 g	1568	87.0	0.6	4.5
Bread**	Heudebert	8 9-g slices	1679	73.0	7.3	11.0
Toast**	Harry's	8 25-g slices	1090	48.5	4.3	7.0
Chocolate cake**	Ker Cadélaç	8 30-g cakes	1812	45.7	25.5	5.3
<b>Extra/topping</b>						
Strawberry jam*	Bonne Maman	100 g	997	59.0	0.1	0.4
Chocolate spread**	Rigoni di Asiago	100 g	2242	54.0	32.0	8.1
Honey**	Lune de Miel	100 g	1365	80.0	0.5	0.5
Cacao powder**	Nesquick	100 g	1540	78.9	3.6	5.1

Butter*	Auchan	8 portions of 12,5 g	3033	0.6	80.0	0.8
<b>Savory foods</b>						
Salami*	Herta	8 10-g slices	1818	1.0	39.0	20.0
Cheese*	Leerdamer	8 25-g slices	1471	0.1	27.5	26.0
Cooked ham*	Herta	8 42.5 slices	437	0.5	2.5	20.0
Mini-sausages***	Auchan	300 g	920	1.3	19.0	11.0
Hard-boiled eggs**	Matines	8 eggs	594	0.5	9.8	13.0
White beans***	Auchan	500 g	303	12	0.5	5.0

183 \*/\*\*/\*\* The items were served cold/at room temperature/hot.

184

### 185 2.3.2. Subjective ratings

186 Appetite, thirst, and thermal assessments (thermal sensation, discomfort and preference) were  
187 assessed 7 times during each session. Appetite was separated into four different perceptions:  
188 hunger, desire to eat, fullness, and prospective consumption. Appetite and liking were assessed  
189 on 100 mm VAS presented on paper preceded by the following questions: “How hungry do you  
190 feel?”; “How strong is your desire to eat something?”; “How full do you feel?”; and “What  
191 quantity of food would you be able to eat?”. These scales were anchored with “not at all” and  
192 “extremely” at the left and right ends, respectively. The distance from the extreme left to the  
193 participant’s vertical dash represented the rating score, expressed in cm. The composite appetite  
194 score (CAS), reflecting the responses to the four VAS questions, was included in the study as a  
195 summary measure of appetite. CAS was calculated using the following formula:  $CAS = ((100 -$   
196  $desire\ to\ eat) + (100 - fullness) + hunger + prospective\ consumption)/4$  (Anderson, Catherine,  
197 Woodend, & Wolever, 2002). These scales have been shown to have a good level of reliability  
198 and reproducibility, and a certain level of predictive validity (Stubbs et al., 2000). Thirst was also  
199 assessed at the same time points as appetite sensations. After dinner, liking of the food items  
200 was assessed using a VAS preceded by the question: “Did you like this food item?”. The self-  
201 selected portion size was also assessed for each item by the question “What amount of food  
202 would have been ideal?” These scales were anchored with “0% of the served portion” and  
203 “200% of the served portion” at the left and right ends, respectively.

204 Thermal sensation (“How do you perceive your thermal environment?”) was determined with  
205 the ASHRAE 7-pt scale (from -3, cold, to 3) and thermal comfort (“How do you perceive your  
206 thermal environment?”) using a VAS with “very uncomfortable” and “very comfortable” at the  
207 left and right ends, respectively. Thermal preference (“What would you prefer at the moment?”) was  
208 assessed using a 5-point NICOL scale (from 2, prefer much cooler to +2, prefer much  
209 warmer) (Humphreys, Nicol, & Raja, 2007).

210 Fatigue and sleep quality were assessed at 7:15am using a VAS preceded by the questions: “Do  
211 you feel tired?” and “Were you satisfied of this night?”, respectively, with “not at all” and  
212 “extremely” at the left and right ends, respectively.

213

### 214 2.3.3. Food reward



215 Food reward for fat and sweet dimensions of foods was assessed using the Leeds Food  
216 Preference Questionnaire (LFPQ) (Finlayson, King, & Blundell, 2008; Finlayson, King, & Blundell,  
217 2007; Oustric et al., 2020). Briefly, liking and IW for 4 categories of food: high-fat-sweet, high-  
218 fat-savory, low-fat-sweet and low-fat-savory were assessed using a computerized task. Explicit  
219 liking (EL) was measured using 100-pt VAS for which participants had to answer to the question  
220 “How pleasant would it be to taste this food now?” with “not at all” and “extremely” at the left  
221 and right ends, respectively. Food images (n = 16) appeared individually on the screen in a  
222 randomized order. IW was assessed using a forced-choice procedure. Every image of each of the  
223 4 food categories was compared to every other image of the 3 other categories (96 pairs in  
224 total). Participants were instructed to respond as quickly as they could to indicate which food  
225 they most wanted to eat at that moment. The IW score is therefore a combination of reaction  
226 time and frequency of selection (Oustric et al., 2020). EL and IW can be summarised as “appeal”  
227 scores (called “appeal bias” in the LFPQ) for fat or sweet foods. Mean savoury scores may be  
228 subtracted from the mean sweet score to provide a “Taste appeal” score. The same procedure  
229 may be applied to high fat relative to low fat foods for the “Fat appeal” score.

230

#### 231 *2.3.4. Temperatures and heart rate*

232 Upon their arrival in the apartment, participants ingested a capsule containing a temperature  
233 sensor (BodyCap, e-Celsius, Caen, France). The capsule is equipped with a memory chip which  
234 allows storage of data in case of loss of connection and communicates with a monitor that  
235 remains with the participants during the whole session. The system was shown to accurately  
236 represent fast changes in water temperature (Bongers, Daanen, Bogerd, Hopman, & Eijsvogels,  
237 2018) and was judged reliable to assess core (Bogerd et al., 2018; Travers, Nichols, Farooq,  
238 Racinais, & Periard, 2016) temperature. Given the timing of ingestion, we acknowledge that first  
239 measurements (between 1 to 3 h) reflect gastric temperatures.

240 Participants were also equipped with three cutaneous sensors. The mean of each measurement  
241 was calculated to determine skin temperature. Then body temperature ( $[\text{skin temperature} +$   
242  $\text{core temperature}]/2$ ) was calculated.

243 Finally, a heart chest strap was fitted (Polar H10, Polar, Kempele, Finland) communicating with a  
244 watch (Polar RC3, Polar, Kempele, Finland) to measure heart rate. The mean was calculated for  
245 3 periods (before the night: 4:00 pm to 10:00 pm; night: 10:00 pm to 7:00 am; morning: 7:00 am  
246 to 8:00 am).

247

#### 248 *2.3.5. Body mass modifications*

249 Body mass was assessed three times (4:00 am, 9:30 pm, and 7:15 am). Food weight was  
250 controlled (dinner) or accurately assessed (breakfast) and was therefore easily determined.

251 Fluid intake was measured using weighing of water bottles. Participants were given cool (~4°C)  
252 500-mL water bottles that were replaced at the beginning of each of these three periods (before  
253 dinner: 4:00 pm to 7:30 pm; dinner and after: 7:30 pm to 10:00 pm: night until breakfast: 9:30  
254 pm to 7:15 am). Their participant code was clearly written on their bottles and they were  
255 instructed to consume as much volume as they desired. If a bottle was finished before the end of  
256 the period, supplementary bottles were available in a fridge.

257 To assess urine loss, a scale was placed very close to toilets. Participants had to weigh  
258 themselves before and after urination and to indicate their participant code and the hour on a  
259 record. The correct filling of the records were frequently checked with participants to ensure  
260 that no weighing were forgotten.

261 Finally sweat loss was calculated using all the aforementioned measurements, considering that  
262 water loss through respiration was negligible (food and water intake – body mass modification –  
263 urine loss).

264

#### 265 *2.3.6. Hydration level*

266 Urine was collected to assess hydration level. Urine specific gravity of the collected urine was  
267 immediately measured with an automated dipstick analyzer (Clinitek Status+ Analyzer, Siemens,  
268 Munich, Germany) using a Multistix10SG (Siemens, Munich, Germany). Values < 1.013 indicate  
269 euhydration (Perrier, Bottin, Vecchio, & Lemetais, 2017), whereas values > 1.020 reflect  
270 hypohydration (Logan-Sprenger & Spriet, 2013).

271

#### 272 **2.4. Statistical analyses**

273 A priori power analysis for EI based on a recent meta-analysis (Millet et al., 2021) selecting  
274 conventional  $\alpha$  (0.05) and  $1-\beta$  (0.80) levels observed that at least twelve participants were  
275 required. All variables were checked for normality using a Shapiro-Wilk test followed by  
276 skewness and kurtosis. In case of absence of normality, logarithmic transformation was  
277 performed. If this transformation did not correct data normality, nonparametric tests were used.  
278 In the case of repeated measurements, mixed-model repeated-measures ANOVA were used.  
279 Thus, appetite and thirst-related VAS scores were compared using a 2x7 ANOVA (temperature  
280 effect: 22 vs 32°C and time effect: 4:00 pm, 6:00 pm, 7:30 pm, 8:00 pm, 9:30 pm, 7:15 am, and  
281 8:00 am). A 2x2 ANOVA was used to compare EL and IW Taste and Fat Appeal scores  
282 (temperature effect: 22 vs 32°C and meal effect: dinner vs breakfast). When the sphericity  
283 assumption was violated (Mauchly's test), a Greenhouse-Geisser correction was used. *Post hoc*  
284 analyses were performed using Bonferroni's tests. The effect of ambient temperature was  
285 assessed using Student t-tests or Wilcoxon rank-sum tests for the remainder of the  
286 measurements. The differences were also examined using Cohen's effect size (ES): > 0.2 (small),

287 > 0.5 (moderate), and > 0.8 (large) (Cohen, 1988). Data are presented as the means  $\pm$  SD.  
 288 Significance was determined as  $p < 0.05$ . Analyses were performed using Jamovi software (1.2.9  
 289 version, the Jamovi project; retrieved from <https://www.jamovi.org>).

290

### 291 **3. Results**

#### 292 **3.1. Breakfast energy intake**

293 EI (Figure 2A and 2B) and macronutrient composition of the meal (in g or % of total EI; Figure  
 294 2A and 2C, respectively) were not different between the sessions ( $p > 0.411$ ,  $d < 0.21$ ). Analysis  
 295 of individual variability using graphs shows that results were very heterogeneous with 7  
 296 individuals increasing and 9 decreasing their EI during the 32 compared to the 22°C session.  
 297 Moreover participants' intake for specific items of the buffet was also not different (data not  
 298 shown). Figure 2D presents the participants' food and drink selection during this meal. They  
 299 selected  $5.8 \pm 2.3$  and  $5.1 \pm 2.1$  items during the 22 and 32°C sessions, respectively ( $p = 0.102$ ,  $d$   
 300  $= 0.32$ ).

301

#### 302 **3.2. Appetite and dinner palatability**

303 No temperature effect was found for hunger score ( $p = 0.580$ ) and CAS ( $p = 0.380$ ). However,  
 304 thirst was significantly higher in the 32 than the 22°C session ( $p < 0.001$ ,  $d = 0.66$ ).

305 At the dinner, palatability for pasta ( $p = 0.317$ ,  $d = 0.26$ ), yoghurt ( $p = 0.135$ ,  $d = 0.14$ ), and  
 306 chocolate ( $p = 0.090$ ,  $d = 0.45$ ) were not significantly different between sessions (Table 2).  
 307 Similarly, self-selected portion size was not different for pasta ( $p = 0.706$ ,  $d = 0.21$ ) and yoghurt  
 308 ( $p = 0.061$ ,  $d = 0.14$ ), but was lower in the 32 than 22°C session for chocolate ( $p = 0.044$ ,  $d =$   
 309  $0.60$ ).

310 **Table 2 -Subjective assessment of dinner with fixed quantities**

	22 °C	32°C
	Palatability (/10)	
Pasta	6.1 $\pm$ 1.9	5.6 $\pm$ 1.8
Yoghurt	7.2 $\pm$ 2.0	7.0 $\pm$ 2.0
Chocolate	7.4 $\pm$ 2.3	6.5 $\pm$ 2.7
	Self-selected portion size (%)	
Pasta	128 $\pm$ 38	122 $\pm$ 33
Yoghurt	119 $\pm$ 38	107 $\pm$ 22
Chocolate	107 $\pm$ 44	90 $\pm$ 48*

311 \*different from 22°C ( $p < 0.05$ )

312

#### 313 **3.3. Food reward**

314 A temperature effect was found in both EL ( $p < 0.001$ ,  $d = 0.56$ , Figure 3A) and IW ( $p < 0.001$ ,  $d =$   
 315  $0.77$ , Figure 3B) for high fat relative to low fat foods (fat appeal). Analysis of individual  
 316 variability using graphs shows that among the 16 participants, a contradictory increase in the fat  
 317 appeal score before dinner was observed in 6 and 4 participants for EL and IW, respectively.

318 This decreased to 2 and 1 before breakfast indicating that results were more homogeneous  
319 before breakfast than before dinner.

320 A meal effect was found for sweet relative to savoury foods (taste appeal) in both EL ( $p < 0.001$ ,  
321  $d = 2.58$ , Figure 3C) and IW ( $p < 0.001$ ,  $d = 3.72$ , Figure 3D), responses being higher before  
322 breakfast than before dinner. Finally, a meal\*temperature interaction in taste appeal score in IW  
323 only ( $p = 0.029$ ). Post hoc tests revealed no further meaningful differences.

324

### 325 ***3.4. Heat-related perceptive and physiological modifications***

326 Core, skin, and body temperatures and heart rate were all higher in the 32 than the 22°C session  
327 ( $p < 0.001$  for all,  $d = 1.03, 2.40, 2.03$ , and  $1.14$ , respectively; Table 3).

328 Water intake ( $p < 0.001$ ,  $d = 3.06$ ), total intake ( $p < 0.001$ ,  $d = 3.33$ ), sweat loss ( $p < 0.001$ ,  $d =$   
329  $2.86$ ), and total loss ( $p < 0.001$ ,  $d = 2.89$ ) were higher in the 32 than the 22°C session while urine  
330 loss ( $p = 0.041$ ,  $d = 0.56$ ) and body mass modifications ( $p = 0.012$ ,  $d = 0.72$ ) were lower (Table 3)

331 Thermal sensation ( $p < 0.001$ ,  $d = 3.44$ ) and discomfort ( $p < 0.001$ ,  $d = 1.67$ ) were higher and  
332 thermal preference lower ( $p < 0.001$ ,  $d = 3.30$ ) in the 32 than the 22°C session (Table 3).

333 Sleep duration reduction in the 32 than the 22°C session was not significant ( $p = 0.084$ ) and  
334 sleep analysis revealed only slight modifications in the 32 than the 22°C session. However, this  
335 analysis was not the primary objective of the article and will not be presented. Fatigue at the  
336 morning was not different between sessions and sleep quality was assessed lower in the 32 than  
337 the 22°C session ( $p = 0.004$ ,  $d = 1.46$ ).

338 **Table 3 – Thermal-related perceptible and physiological markers**

	22 °C	32°C
Core Temperature (°C)	36.7 ± 0.3	37.0 ± 0.3***
Skin Temperature (°C)	34.7 ± 0.6	35.9 ± 0.4 ***
Body Temperature (°C)	35.7 ± 0.4	36.4 ± 0.3***
Heart Rate (bpm)	65.9 ± 6.1	73.0 ± 6.3***
Δ Body mass (kg)	0.38 ± 0.40	-0.05 ± 0.50*
Food intake (kg)	1.00 ± 0.26	1.05 ± 0.27
Water intake (kg)	0.60 ± 0.31	1.50 ± 0.50***
Total intake (kg)	1.60 ± 0.38	2.55 ± 0.53***
Urine loss (kg)	0.91 ± 0.33	0.79 ± 0.32*
Sweat loss (kg)	0.30 ± 0.18	1.81 ± 0.64***
Total loss (kg)	1.21 ± 0.44	2.60 ± 0.66***
Thermal sensation (-3 ;+3)	-0.49 ± 0.55	1.44 ± 0.49***
Thermal discomfort (/10)	3.7 ± 1.9	6.3 ± 1.1**
Thermal preference (-2 ; +2)	0.34 ± 0.37	-0.93 ± 0.40***
Sleep duration (min)	478 ± 26	456 ± 62
Fatigue score (/10)	3.77 ± 2.00	4.84 ± 2.37
Sleep quality (/10)	6.99 ± 2.11	3.82 ± 2.23**

339 Different from 22°C (\* $p < 0.05$  ; \*\* $p < 0.01$  ; \*\*\* $p < 0.001$ )

340 USG was found slightly lower at 4:00 pm in the 32 than the 22°C session ( $1.020 \pm 0.006$  vs  $1.024$   
 341  $\pm 0.005$ , respectively;  $p = 0.036$ ,  $d = 0.72$ ). USG were found similar between 32 and 22°C sessions  
 342 at 9:30 pm ( $1.019 \pm 0.006$  vs  $1.019 \pm 0.004$ , respectively;  $p = 1.000$ ) and 7:15 am ( $1.026 \pm 0.006$   
 343 vs  $1.027 \pm 0.007$ , respectively;  $p = 0.270$ ).

344

#### 345 4. Discussion

346

347 The aim of this study was to assess the impact of heat exposure on hunger sensations and EI and  
 348 its impact on food reward before two different meals (dinner and breakfast) during a long  
 349 sedentary period (16 h). Contrary to our hypothesis, heat exposure did not modify appetite or *ad*  
 350 *libitum* breakfast EI and only very slightly impacted subjective assessments (palatability and  
 351 self-selected portion size) of the fixed dinner meal. However, liking and wanting for high-fat  
 352 foods relative to low fat foods were decreased before both meals.

353

354 Several studies have reported modifications of appetite and EI during or after heat exposure.  
 355 Subjective hunger was found diminished just after (Kojima et al., 2015) and up to 2 h (Wasse et  
 356 al., 2013) after an exercise session in the heat compared to a thermoneutral condition. In a  
 357 recent study (Zakrzewski-Fruer et al., 2021) with a design similar to this study (sedentary 4-h  
 358 exposure at 30 °C compared to 20 °C), appetite scores were decreased during the whole  
 359 exposure. *Ad libitum* EI at lunch was found to decrease by  $1189 \text{ kJ} \pm 1219 \text{ kJ}$  in the same study.  
 360 Concordant results were found after an exercise session using two consecutive cold buffet-style  
 361 meals ( $-1400 \pm 2345 \text{ kJ}$  at 30 compared to 20°C,  $p = 0.08$  (Wasse et al., 2013)) and a buffet-type  
 362 breakfast (EI increased after an exercise session at 25°C compared to a rest session at 25 °C but  
 363 not after the same exercise at 36 °C (Shorten et al., 2009)). Although effects were less

364 pronounced in other studies (Ahmed et al., 2019; Faure et al., 2016; Laursen et al., 2017), a  
365 recent meta-analysis (Millet et al., 2021) highlighted a very likely anorexigenic effect of heat  
366 independently of performing an exercise session. Real-life condition studies are very rare but  
367 results from a recent one (Zheng, Li, & Wang, 2019) suggested blunted levels of hunger on hot  
368 days (34-36 °C) compared to milder ones (28-30 °C). Although this study was designed to focus  
369 on the effects of heat exposure in removing or limiting numerous biases (no physical exercise,  
370 standard and similar clothing, and *ad libitum* water intake), hunger scores and EI during an *ad*  
371 *libitum* buffet breakfast were not influenced by the thermal environment therefore contradicting  
372 results from the aforementioned studies. This lack of effect remains to understand and explain  
373 especially when a very similar study (Zakrzewski-Fruer et al., 2021) found a strong and  
374 homogenous response during exposure to heat.

375

376 The main explanation we can offer for the discrepancy in findings is related to the nature of the  
377 test meal. Zakrzewski-Fruer et al (Zakrzewski-Fruer et al., 2021) selected an *ad libitum* pasta  
378 dish served at lunch after 4 h of heat exposure (30 °C vs 20 °C). In the present study, a buffet  
379 breakfast containing foods and drinks varying in temperature (served cold, at ambient  
380 temperature, or hot), fat content (from low to high-fat), and taste (savory or sweet) was  
381 retained. This choice was made for two main reasons: 1) this procedure has been shown reliable  
382 and reproducible (Chaput et al., 2016; McNeil, Riou, Razmjou, Cadieux, & Doucet, 2012; Thivel,  
383 Genin, Mathieu, Pereira, & Metz, 2016), 2) the variety of items partially reproduced the variety of  
384 the food list used in the LFPQ allowing therefore observation of similar responses between  
385 actual intake and LFPQ responses (Dalton, Blundell, & Finlayson, 2013; Kapoor et al., 2021).  
386 Moreover, since we only considered the measurements realized during the second session of  
387 both thermal conditions, we theoretically removed the likely over-consumption and selection of  
388 different items at each session for the purpose of variety (Stubbs, Johnstone, Mazlan, Mbaiwa, &  
389 Ferris, 2001). This choice did not lead to modifications of EI when exposed to heat and only  
390 induced slight differences in food selection between thermal conditions indicating that  
391 participants mostly ate the same kind of items. These observations are only partially surprising.  
392 Indeed, contrary to other meals, breakfast composition characterized by strong habits. In a  
393 survey realized in 771 Irish adults, only 17% modified the composition of their breakfast each  
394 day (Gibney & Uzhova, 2019). Moreover, specifically in France, a large majority of children and  
395 adults (~90%) consumed a breakfast with a high content in carbohydrates (Gibney et al., 2018;  
396 Lopicard, Maillot, Vieux, Viltard, & Bonnet, 2017). Thus, even with a buffet theoretically allowing  
397 the choice of items with different fat and carbohydrates content, it cannot be excluded that this  
398 usual high level of carbohydrates intake may conceal the expression of modifications of  
399 preferences for the different items. In these conditions, EI would have required very strong

400 modulators to be affected, and an increase of 10 °C was probably not sufficient to change these  
401 strong habits.

402

403 Two other hypotheses surrounding the choice of the buffet breakfast were: 1) low hunger  
404 scores, and 2) the duration between the end of the meal and the end of the study. Concerning the  
405 former point, we did not expect such low hunger scores (~ 4 cm on a 10-cm scale) since we  
406 respected participants' habits in terms of sleep duration, sleep usual awakening time, and delay  
407 between awakening and breakfast initiation and since we recruited habitual breakfast eaters.  
408 Amongst the 16 participants, only two ate their breakfast with hunger scores higher than 5 cm  
409 and most of them probably ate in the absence of hunger. Studies in which hunger is assessed  
410 before breakfast generally report hunger scores twice the levels in the present study (6-8 cm)  
411 (Robert A. Corney, Horina, Sunderland, & James, 2015; McNeil et al., 2017; Radcliffe et al., 2021;  
412 Thomas, Higgins, Bessesen, McNair, & Cornier, 2015; Zakrzewski-Fruer et al., 2021). However,  
413 analysis of these protocols revealed a 60 to 90 min delay between the awakening and the VAS  
414 filling allowing hunger to grow. In a study in which hunger scores were assessed at 7:30 am, 30  
415 min after awakening, 3 to 4-cm response were reported indicating that the hunger scores in the  
416 present study were not unusual. Nevertheless, this could participate to the lack of expression of  
417 environmental effect on subjective scales, hidden by a certain cognitive inertia classically  
418 described for all subjective assessments during the 15 to 60 minutes following awakening  
419 (Hilditch & McHill, 2019). In these conditions of low hunger VAS, the observation of a reduction  
420 in EI is less likely. Concerning the second hypothesis, one recent study highlighted an effect of  
421 the defined postprandial delay on breakfast EI. It was found that EI was lower when participants  
422 knew that they could leave the laboratory as soon as the 30-min period allocated to eat elapsed  
423 compared to an imposed 1 or 3-h stay after (Palmer, Irwin, McCartney, Cox, & Desbrow, 2021).  
424 Participants were obliged to remain in their rooms until 8:15 am (45 min after the beginning of  
425 the meal). They were then allowed to remove equipment and to take a shower. Considering the  
426 results of this study, which was not published when the present study was designed, it is  
427 possible that participants have rushed to leave the unit, altering their food intake. It is difficult to  
428 weigh the importance of this possible explanation, but it is quite reasonable to think that the  
429 procedure used in the present study at least partly blunted food/drink choice and intake.

430

431 An effect of heat exposure on food reward was examined for the first time in the present study. It  
432 has already been used in extreme environments such as cold (Charlot et al., 2021) or hypoxia  
433 (Aeberli et al., 2013; Karl et al., 2018) but never in a laboratory context with a control condition.  
434 In the present study, a clear heat-induced decrease of liking and wanting for high-fat foods  
435 (decrease in the fat appeal score for EL and IW) was found before each meal (dinner and

436 breakfast) suggesting that being acutely exposed to heat may potentially reduce the selection of  
437 high-fat foods in favor of lower fat ones. Moreover, this response was found in the large majority  
438 of participants (~90% before breakfast) reflecting its robustness. However, these specific  
439 modifications of food reward were not accompanied by coherent modifications of food choice or  
440 EI contrary to previous studies linking LFPQ responses and actual choices (Dalton et al., 2013)  
441 or self-reported preference for fat taste and high-fat food intake (Chmurzynska et al., 2021). As  
442 explained earlier, the modalities of the *ad libitum* test meal selected for this study were possibly  
443 not the best option to objectify these modifications in food reward. Moreover, one might argue  
444 that, despite being able to choose foods with different fat content, participants did not correctly  
445 identify the fatness of proposed foods blurring therefore the associations between the responses  
446 during the LFPQ and the choices made during the buffet. Interestingly, subjective assessment of  
447 the three imposed items during the dinner showed that chocolate bar, the item with the highest  
448 relative fat content, was the one that was the most depreciated in the 32 vs 22 °C session. It  
449 remains hypothetical since these foods were not specifically chosen to observe such  
450 relationships but it supports the link between heat exposure and preference for high-fat foods.  
451 Studies assessing the direct influence of acute the direct influence of acute or long heat exposure  
452 on food choice is almost non-existent. Studies on seasonal variations indicate that EI is higher in  
453 winter than summer (Stelmach-Mardas et al., 2016) probably through modifications in food  
454 choice (fruits and vegetables, cereals dairy). However, these changes were likely influenced by  
455 their availability (pre or post-harvest) and effects of heat are therefore hypothetical.

456  
457 No effect of the temperature in the taste appeal score (liking or wanting for savory over sweet  
458 items) was observed in this study. This may be contradictory with some articles suggesting a  
459 link between between hydration level, exercise-induced salt loss, and/or thirst sensation and the  
460 preference for salt (Leshem, Abutbul, & Eilon, 1999; Takamata, Mack, Gillen, & Nadel, 1994). It  
461 was indeed hypothesized that sodium loss in sweat may increase desire for salt and savory foods  
462 and drinks in order to prevent more loss and to maintain osmoregulation. However, this  
463 mechanism is contradicted by several studies in which sodium loss did not induce excess salt  
464 appetite (Carroll et al., 2019; Leshem, 2009). The present results rather support the last  
465 hypothesis. The effect of heat exposure on other dimensions of food would be interesting to  
466 assess starting with the temperature of the served foods. Indeed, it is now well demonstrated  
467 that oral temperature sensing in the mouth may influence ingestive acceptance (Lemon, 2021)  
468 and that cold drinks but also cold foods may be perceived as more pleasant in the heat (Burdon,  
469 Johnson, Chapman, & O'Connor, 2012) through higher ability to satiate thirst (Eccles, Du-Plessis,  
470 Dommels, & Wilkinson, 2013). Other dimensions such as the texture, the color, and/or the taste  
471 are interconnected with food/drink temperature since these dimensions may be influenced by



472 the coldness/warmth of ingested items or influence the perception of the served temperature  
473 (Labbe et al., 2009; Motoki, Saito, Nouchi, & Sugiura, 2020; Suzuki et al., 2017).

474

475 Assessing appetite and food intake is a complex task (Gibbons, Hopkins, Beaulieu, Oustric, &  
476 Blundell, 2019) requiring making choices during the design of the protocol (Gregersen et al.,  
477 2008; Horner, Byrne, & King, 2014; Laan, Leidy, Lim, & Campbell, 2010; Thivel et al., 2016) that  
478 may lead to limited conclusions. Adding the thermal matter into this field necessarily adds  
479 supplemental limitations. As explained in this recent meta-analysis (Millet et al., 2021), no  
480 consensus exists in the adequate modalities of thermal exposure (temperature, humidity,  
481 duration of exposure, clothing, water intake management). The choices made may be therefore  
482 somewhat arbitrary and may influence the obtained results. In this article, a lot of effort was  
483 made to ensure that ambient temperature was the only difference between sessions. Clothing  
484 activities and hydration status were similar. We found that heat-related physiological (core, skin,  
485 and body temperatures, HR, sweat loss) and subjective markers (thermal discomfort, sensation,  
486 and preference) were strongly impacted by the exposure to 32 °C compare to 22 °C. These  
487 differences, although not surprising since similar studies (Faure et al., 2016; Zakrzewski-Fruer  
488 et al., 2021) indicate that the exposure to 32°C induced very large and concordant differences in  
489 physiological and subjective thermal markers. Moreover, although providing them free access to  
490 cool water during and between the meals to avoid imposing them large amounts of water that  
491 may be felt as uncomfortable as others (Wasse et al., 2013), water loss was replaced by ad  
492 libitum water intake leading to neutral water balance. Participants were therefore at worse  
493 slightly less hydrated in the 32 than the 22 °C. Since, severe dehydration (between -1 and -3% of  
494 body mass) does not appear to modify EI (Carroll et al., 2019; Robert Anthony Corney,  
495 Sunderland, & James, 2015) even during a semi-solid breakfast (Robert A. Corney et al., 2015),  
496 heat-induced perturbations in water balance were not certainly considered a bias in the present  
497 study. Another potential limitation of this study would be the influence of heat on sleep duration  
498 and quality that may be altered during heat exposure (Libert et al., 1991; Okamoto-Mizuno &  
499 Mizuno, 2012; Zheng et al., 2019). Only marginal alterations of sleep architecture (data not  
500 shown), duration, and fatigue score were reported in this study. This result is crucial in the  
501 context of the present study since sleep restriction may modify EI (Radcliffe et al., 2021;  
502 Soltanieh, Solgi, Ansari, Santos, & Abbasi, 2021) and food reward (McNeil et al., 2017). However,  
503 these perturbations seem observable with less than 6-h sleep (Soltanieh et al., 2021) and/or if  
504 sustained over several days (Calvin et al., 2013). Milder sleep deprivation/perturbation as in the  
505 present study was generally not associated with EI modifications (Morrison et al., 2021). It was  
506 concluded that all measurements related to food intake were unlikely to be influenced by heat-  
507 induced sleep-alterations. Finally, a slight effect of differences in menstrual cycle may exist.

508 Indeed it has been clearly showed that EI is higher during the luteal than the midfollicular and  
509 the periovulatory phases (Asarian & Geary, 2013). Study constraints (4 participants per group,  
510 and 2-d inertia of temperature modifications in the apartment) impeded us to plan the sessions  
511 in the same phase for each female participant. However, at the exception of one participant that  
512 realized both sessions in different phases (luteal then periovulatory phases), the eight other  
513 were in the same phase (5 in luteal, 2 in the early-follicular, and 1 in the midfollicular phase). It  
514 is therefore possible that results for women may have been slightly altered.

515

## 516 **5. Conclusions**

517

518 In this study, 16-h passive exposure to heat (32 °C, 40 % RH) modified food reward with a  
519 decrease in liking and wanting for high fat relative to low fat foods in comparison to a  
520 thermoneutral condition (22 °C, 40% RH). Surprisingly, hunger feelings were not modified  
521 during the whole exposure and the absence of modifications in actual food choice or EI during an  
522 *ad libitum* breakfast buffet did not reflect the changes in food reward. Although these apparent  
523 contradictory results remain to be understood, the lower preference for high-fat foods may  
524 explain the heat-induced decrease in EI observed in previous studies indicating that acute EI  
525 modifications are not necessarily driven by hunger modifications but could be altered by reward  
526 value of energy dense foods. The effects of a longer exposure with several successive meals and  
527 the analysis of food reward for other dimensions (such as temperature and texture) that may be  
528 impacted by ambient temperature should be assessed to better identify the effects of heat  
529 exposure on appetite. Moreover, the effect of gender on heat-induced modifications of EI and  
530 food reward deserved to be specifically assessed since men and women are known to differently  
531 experience similar thermal environments (Karjalainen, 2007). This was not the primary aim of  
532 this study and it lacked of statistical power to realize adequate analyses.

533

534

## 535 **Ethical statement**

536 This study was conducted according to the guidelines laid down in the Declaration of Helsinki  
537 and all procedures were approved by the French National Ethics Committee Sud Méditerranée  
538 n°2 (2021-A01238-33). Written informed consent was obtained from all participants who  
539 received financial remuneration for study completion.

540

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543 Deshayes.

544

545 **Conflict of interest**

546 No potential conflicts of interest relevant to this article were reported.

547

548 **Authors contribution**

549 KC and JM designed the study. KC, JM, FP, PVB, JM, FS, PETD, and investigators group realized the  
550 experiment and collected the data. KC and JM processed data and conducted the statistical  
551 analyses. Laboratoire graphique (KC) designed the figures. KC drafted the initial manuscript. All  
552 authors reviewed and revised the manuscript, approved the final manuscript as submitted, and  
553 agree to be accountable for all aspects of the work.

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556

557 **Data availability statement**

558 The datasets generated and analyzed during the current study are available from the  
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825 **Figure legends**

826

827 **Figure 1 - Study protocol.** RH = relative humidity, LFPQ = Leeds Food Preference  
828 Questionnaire.

829

830 **Figure 2 - Absolute (A) and relative (C) macronutrient macronutrient intake, energy**  
831 **intake (B) and the amount of consumed items (D) at the ad libitum breakfast-buffet.** For  
832 Figures A and C, each bar indicates individual data ranged by total energy intake and relative  
833 carbohydrate intake, respectively. Horizontal lines indicate the mean for each macronutrient.  
834 For Figure B, bars indicate the means and the grey lines the individual values. For Figure D, grey  
835 bars indicated the number of items that were selected in both conditions by the same  
836 participants. Blue and red bars exceeding the grey bar indicated the number of items that were  
837 only selected in 22 and 32°C sessions, respectively. PRO = protein, CHO = carbohydrates.

838

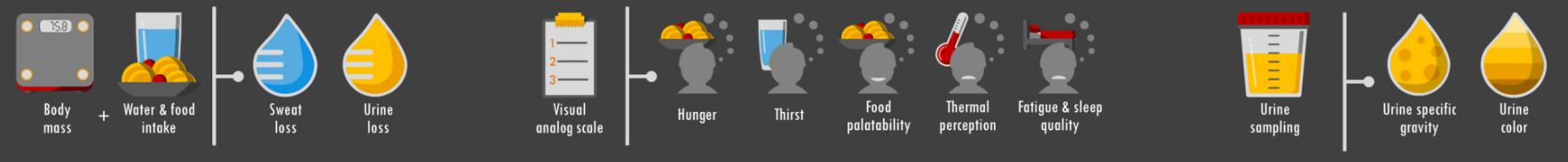
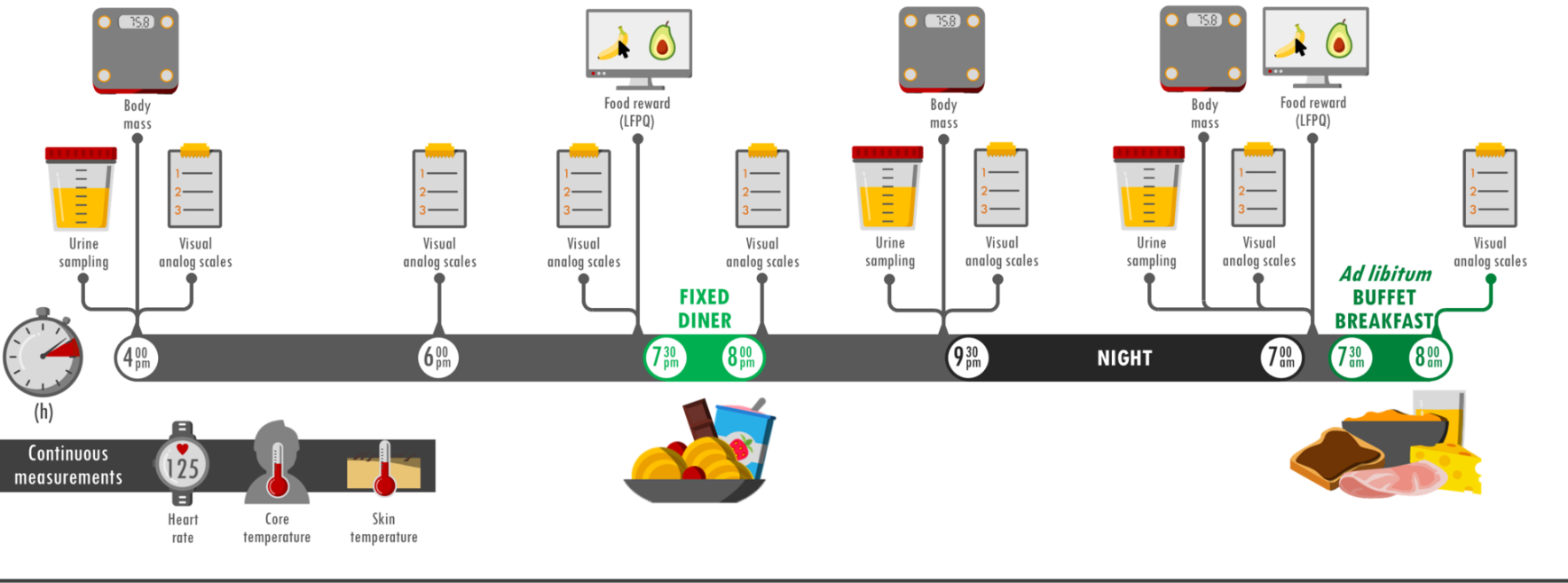
839 **Figure 3 - Hunger (A) and thirst (B) scores during the whole exposure.** Means  $\pm$  SD. 0 h =  
840 16:00 pm. Grey bars symbolizes meals and black bar the sleep period. \*\*\* different from 22°C  
841 session ( $p < 0.001$ ).

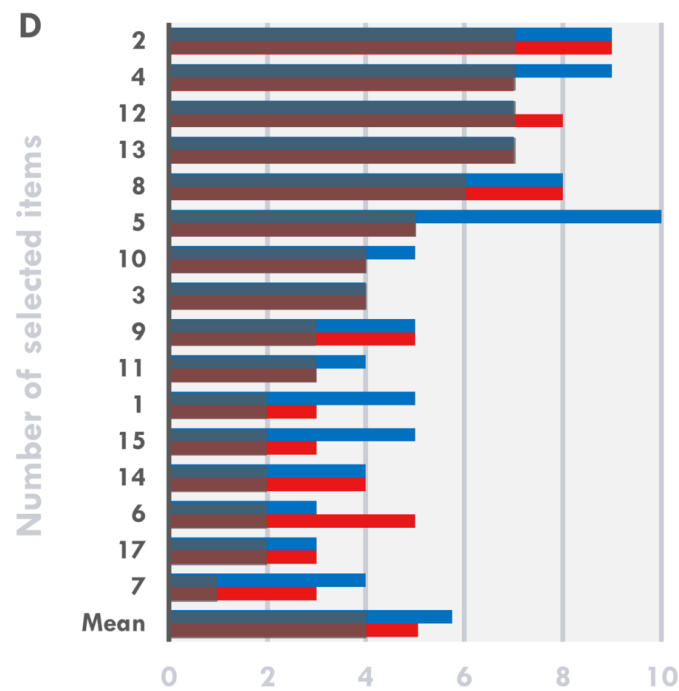
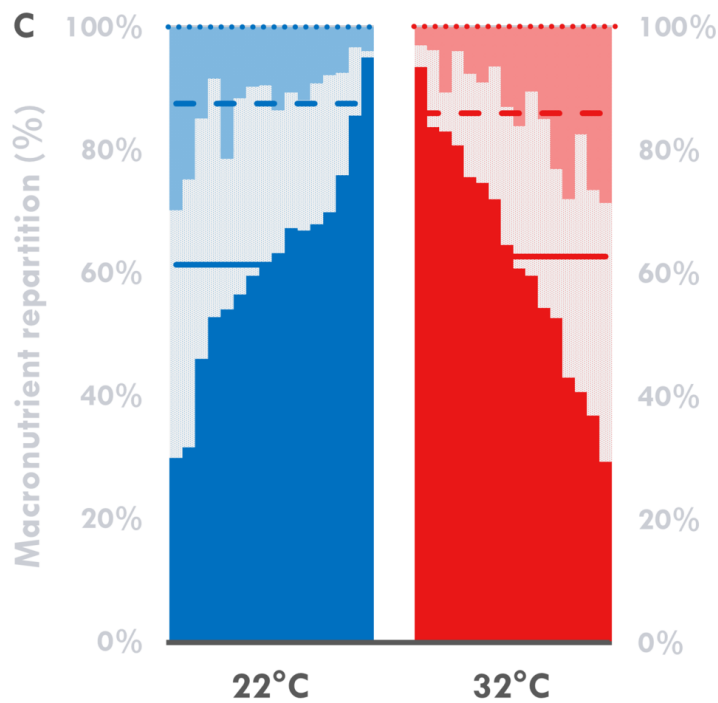
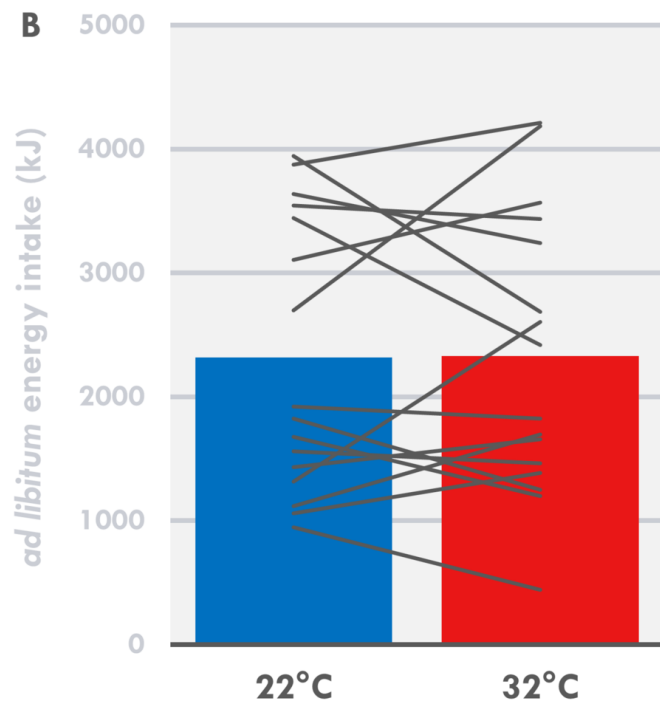
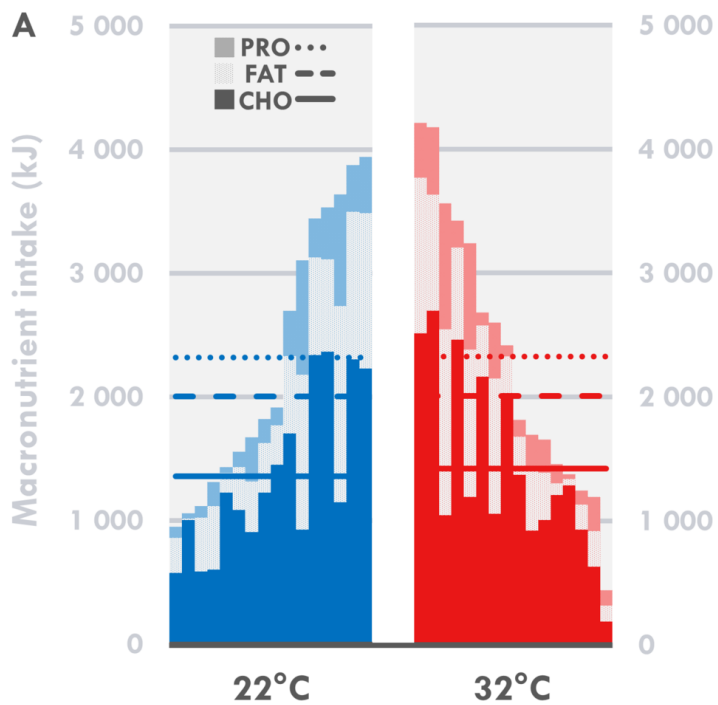
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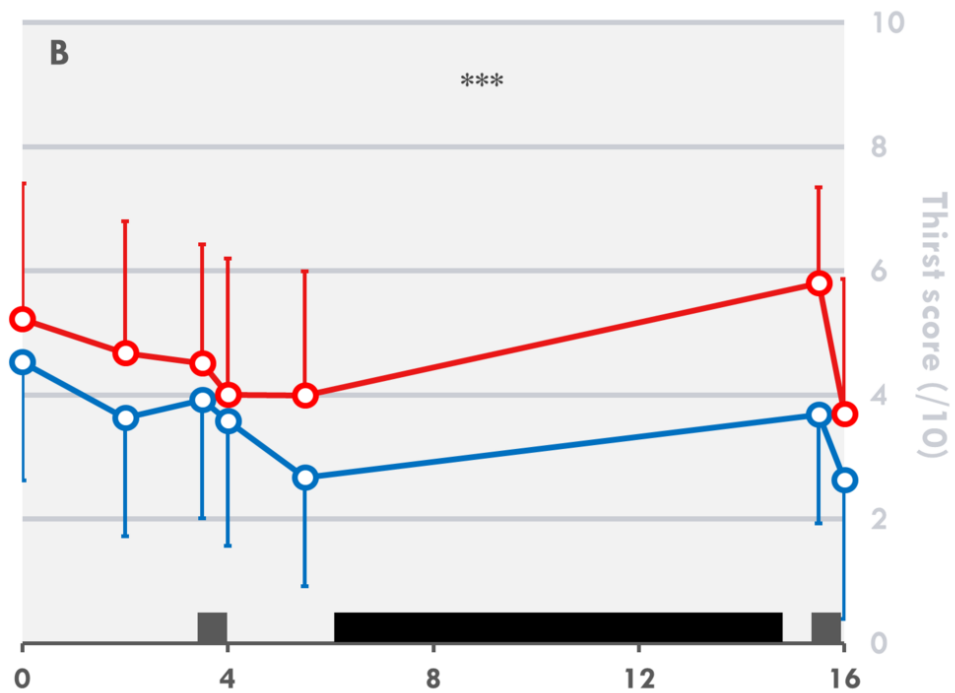
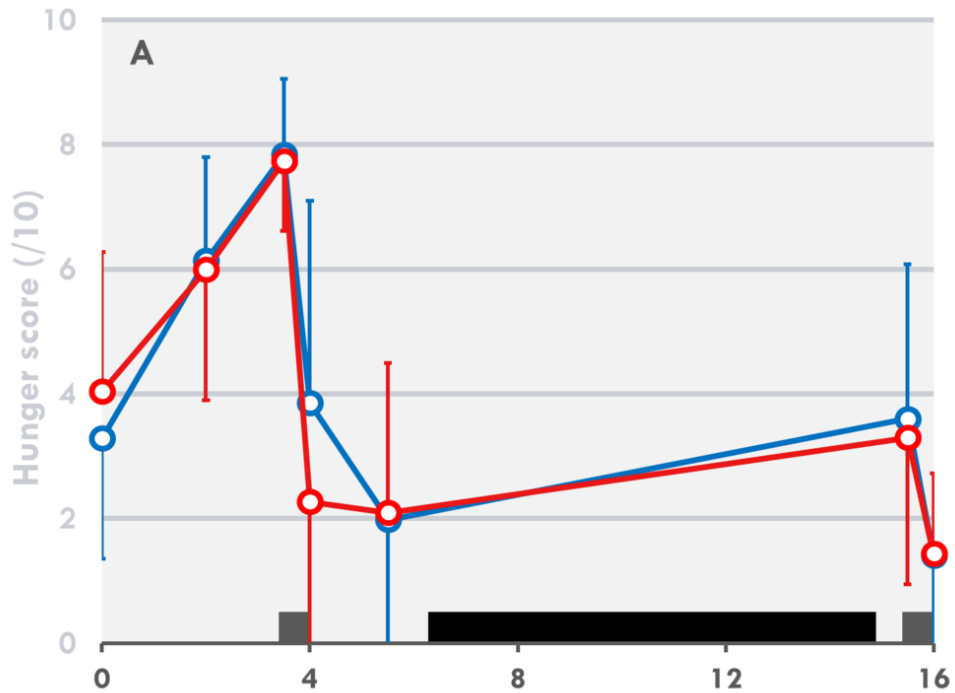
843 **Figure 4 - Fat and Taste appeal scores before dinner and breakfast.** Values for explicit  
844 liking (A and C, respectively) and implicit wanting (B and D, respectively). The bars indicates the  
845 means and the grey lines the individual values. \*\*\*different from 22°C session ( $p < 0.001$ );  
846  $\alpha\alpha\alpha$ different from the dinner ( $p < 0.001$ ).

22 °C vs 32 °C  
40% RH vs 40% RH

4 participants per session  
1 month between sessions



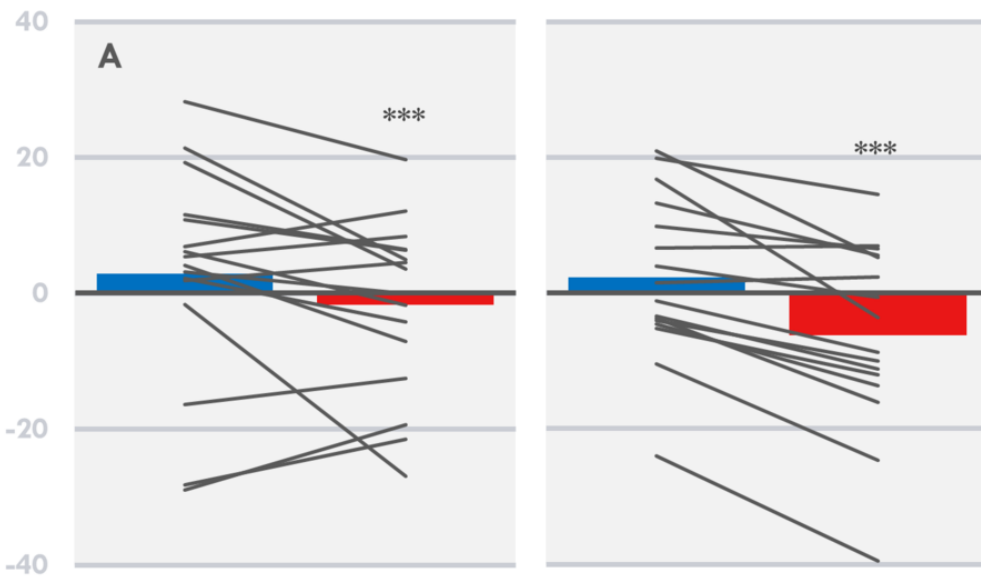




## Explicit liking

Before dinner

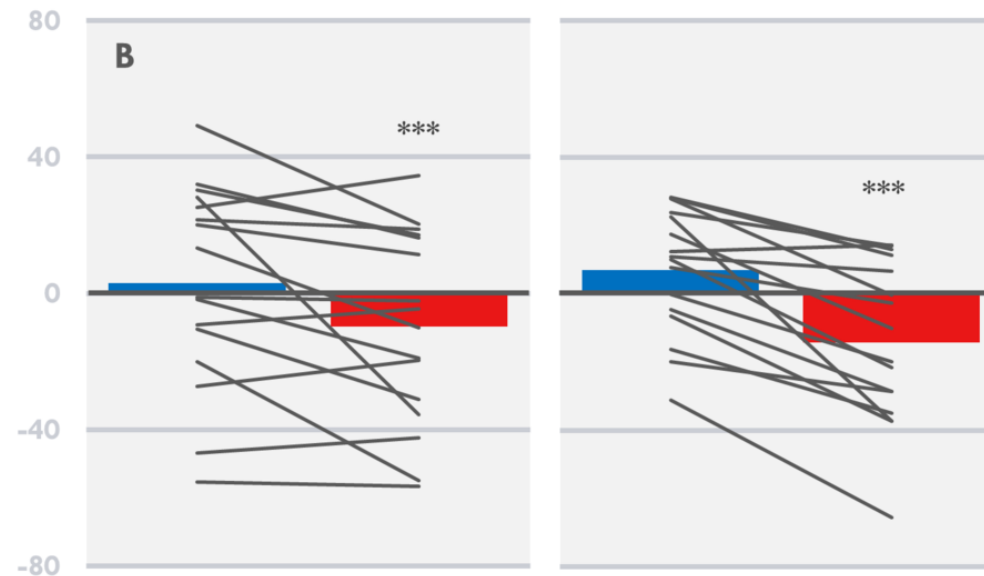
Before breakfast



## Implicit wanting

Before dinner

Before breakfast



Taste appeal

