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Title: Development of the Leeds Food Preference Questionnaire in Japanese: Sensitivity and reproducibility of liking and wanting for food in fasted and fed states

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Abstract

The Leeds Food Preference Questionnaire (LFPQ), a computer-based task for measuring reward responses (liking/wanting) and preferences for images of food, is a widely used tool. However, no cultural adaptation studies to date have addressed its validity and repeatability in a test-retest design. The present study aimed to develop a Japanese version of the LFPQ (LFPQ-J); examine its outcomes under fasted and fed states; and test its reproducibility after one week. An online survey containing foods that were either low-fat sweet, high-fat sweet, low-fat savoury or high-fat savoury was first conducted among a sample of 200 Japanese adults (100 men and 100 women) to develop and validate a culturally appropriate food image database. Sixty participants (30 men and 30 women) then participated in two identical trials where they completed the LFPQ-J under fasted and fed states (immediately after a standardised meal), at least one week apart. The absolute difference within the participants in scores for explicit liking, explicit wanting, implicit wanting and relative preference between the trials was analysed using Bland-Altman plots and Pearson's or Spearman's correlation coefficients. In the fasted state for each food category, 91.1 to 96.4 % of the data were plotted within the 95% limits of agreement and intra-personal correlation were 0.58 - 0.81. In the fed state for each food category, 91.1 to 98.2 % of the data were plotted within the 95% limits of agreement and intra-personal correlation were 0.40 - 0.83. The present study demonstrates that the LFPQ-J is a sensitive and reproducible instrument for the evaluation of liking and wanting for food varying in fat content

and sweet taste in Japanese adults.

Key words: Food reward, Leeds Food Preference Questionnaire, Liking, Wanting

Abbreviations:

LFPQ: Leeds Food Preference Questionnaire

LFPQ-J: Leeds Food Preference Questionnaire in Japanese

HFSA: high-fat savoury

LFSA: low-fat savoury

HFSW: high-fat sweet

LFSW: low-fat sweet

TFEQ: Three Factor of Eating Questionnaire

1. Introduction

Appetite is regulated by a complex system of central and peripheral signals acting on homeostatic and hedonic systems of the brain that mediate hunger or satiety (Berthoud, 2011). The homeostatic system is coordinated via tonic processes, and episodic processes for controlling hunger and satiety (Blundell, Gibbons, Caudwell, Finlayson, & Hopkins, 2015; Blundell et al., 2020). The hedonic system is coordinated in the reward system of the brain mediated by dopamine and endogenous opioids (Lutter & Nestler, 2009), and it manifests through "liking" and "wanting" for certain foods, providing a direction and intensity to the motivation to eat (Finlayson & Dalton, 2012).

The Leeds Food Preference Questionnaire (LFPQ) is a computer-based task, designed to measure separable processes of liking and wanting for food (Finlayson et al., 2007). The traditional LFPQ measures explicit liking and wanting directly and implicit wanting indirectly using 16 images of foods that are either high-fat savoury, low-fat savoury, high-fat sweet or low-fat sweet. The widespread use and adaptation of the LFPQ has been identified as a need to develop reliable cultural adaptations and improve the quality of data (Oustric et al., 2020). However, no previous studies have validated a cross-cultural adaptation of the LFPQ and confirmed its sensitivity and repeatability in a test-retest design. In the issue of reproducibility, for example, a previous study that used the original British LFPQ without performing a cultural

adaptation of the food images for their country observed imperfect suitability of the translated LFPQ for the targeted population due to lack of familiarity with the food images (Leenaars et al., 2016). This indicates that a cultural adaptation of the LFPQ may be necessary since cultural factors play a major role in food choice, selection and consumption (Carvalho-Ferreira et al., 2019). Indeed, regarding the importance of establishing the cross-cultural validity of food preference tools (Alkahtani et al., 2016), it has been suggested that the differences in food culture influence fat and sweet preferences (Tiu Wright, Nancarrow, & Kwok, 2001). In addition, it has demonstrated that the LFPQ is responsive to manipulations of hunger state which is consistent with sensory-specific satiety (Oustric et al., 2020), and has reported that implicit and explicit processes of food reward can be simultaneously measured and dissociated using test meal (Finlayson et al., 2008). Furthermore, it has been suggested that negative and positive energy balance may have opposing effects on the result of the LFPQ (Thackray et al., 2020). Therefore, it is important to standardise a test meal and energy balance (i.e., energy intake or physical activity) when testing the sensitivity and repeatability of the LFPQ.

The present study aimed to develop a Japanese version of the LFPQ for healthy adults, and test its sensitivity and repeatability by comparing the LFPQ scores obtained in the fasted and fed states on two occasions, at least one-week apart, under identical conditions.

2. Methods

To meet the aims of the present study, two steps were performed: the development of a culturally suitable Japanese version of the task and the validation of the task, according to a standardised procedure recommended in a previous review (Oustric et al., 2020). For the former, a food image (i.e., picture) database was created and validated for the Japanese population, and all the text from the task was translated into Japanese. The latter was an experimental procedure which was conducted to test the sensitivity and repeatability of this new version of the LFPQ for a Japanese adult population (LFPQ-J).

2.1. Food image validation

A pool of 32 food images was chosen by registered dietitians. High and low-fat foods were defined as greater than 40% and lower than 20% of the energy from fat, respectively. Selection criteria for the 16 foods used in the task were: 1) ready to eat form, 2) limited variety, 3) typical presentation and portion size, 4) appropriate to the time of the day of the measurements, 5) appropriate to the culture and habits of the targeted population, diversity of food within each category and 6) homogeneity of the image background (Oustric et al., 2020).

Perceptual characteristics of the chosen food images were validated using an online survey in a sample of 200 non-dieting Japanese adults (100 men and 100 women, age range: 20 to 50

years, stratified for age with 25 men and 25 women in each decade) living in various geographic regions of Japan. The survey asked for recognition, frequency of eating, liking, perception of fat content and taste (fatty; low fat or high fat, and taste; sweet or savoury), and appropriateness to eat at different meal times (breakfast, lunch, and dinner) (Oustric et al., 2020). The final set of 16 food images can be viewed in Supplemental Figure 1. The remaining four food images in each category were used as substitutions in case individuals could not eat or did not like any of the four images selected in each category.

2.2. Development of Japanese version of the LFPQ (LFPQ-J)

The LFPQ is a computer-based task to assess the different components of food preference and food reward. Sixteen ready-to-eat food images which are common in the Japanese diet were chosen from a validated food image database (Supplemental Figure 1). The images were categorised into four categories including HFSA, LFSA, HFSW and LFSW. This categorisation is based on the final set of sixteen food images with four foods in each category via the food validation. Text from the original version of the LFPQ (Finlayson et al., 2007) was translated into Japanese by one of the authors, a Japanese native speaker with advanced level of English language proficiency, and Japanese version of text was back-translated into English by a bilingual English-Japanese speaker who works at a scientific language editing company to strengthen the validity of the translated task. This backward-forward translation process was

repeated until the questions were matched in terms of meaning and cultural appropriateness.

2.2.1. Explicit liking and explicit wanting

Explicit liking and wanting were measured using a 100-mm visual analogue scale. Single food images were randomly shown to the participant and participants responded according to the following two questions, “How pleasant would it be to taste some of this food now?” (explicit liking) and “How much do you want some of this food now?” (explicit wanting), anchored at each end with “not at all” and “extremely”.

2.2.2. Implicit wanting and relative preference

Implicit wanting and relative preference were measured using a forced choice methodology. A series of food image pairs were presented to participants and they were asked “Which food do you most want to eat now?”. These food pairs were presented in a total of 96 pairs, such that all food images from one category were presented with each food from the other categories. Participants were asked to select the food they want to eat the most at that moment as quickly and as accurately as possible via key press on the keyboard. The exclusion criteria for response time were shorter than 100 ms or longer than 4000 ms. The frequency of choice and non-choice, and the reaction time of each task for each food category were recorded and the implicit wanting score was calculated as in the following formula (Oustric et al., 2020). A positive score

148 indicates a greater preference for a given food category relative to the alternatives in the task
149 and a negative score indicates the opposite. A score of zero would indicate that the category is
150 equally preferred.

151

152 Frequency – weighted algorithm: $I_A = \sum_{i=1}^{N_{choice}} \frac{\bar{t}}{t_i} - \sum_{i=1}^{N_{non-choice}} \frac{\bar{t}}{t_i}$

153 Formula legend: I_A = Implicit wanting for category A; N_{choice} = number of times category A was
154 selected; $N_{non\text{-}choice}$ = number of times category A was not selected; $\bar{t}$ = mean of all reaction
155 times (Oustric et al., 2020).

156

157 **2.2.3. Fat appeal bias and taste appeal bias**

158 Bias scores for fat content and taste were computed by subtracting the mean low-fat scores
159 from the mean high-fat scores, and the mean savoury scores from the mean sweet scores,
160 respectively. Positive values indicate a preference for high-fat or sweet foods, negative values
161 indicate a preference for low fat or savoury foods and a score of 0 indicates an equal preference
162 between fat content and taste categories.

163

164 **2.3. Experimental procedure for validation of the LFPQ-J**

165 **2.3.1. Participants**

166 A participant flow diagramme is shown in Figure 1. Inclusion criteria included healthy

Japanese adults 20 - 29 years in age who are currently non-smoking, BMI 18.5-29.9 kg/m^2, and not having chronic diseases. Participants of the present study were recruited between May 2021 and November 2021 through advertisements placed on the campus. Sixty-four healthy Japanese adults provided written informed consent to participate in the study and 60 participants completed this study. We analysed 56 (26 men and 30 women) participants' data as we were unable to obtain physical activity data (i.e., the day before each main trial) from four participants.

Please insert Figure 1 near here.

2.3.2. Preliminary tests

After measurement of anthropometry (height, body mass, body composition, waist circumference and blood pressure) in the morning or afternoon under the non-fasted state, participants filled out the Japanese version of Three Factor of Eating Questionnaire (TFEQ). Then, the LFPQ-J screening test was conducted. Participants were asked to write the name, whether they had eaten before or not, and whether they would be able to eat the 16 foods presented on the LFPQ-J or not. If there were some foods which participants had not eaten or were not able to eat, the food was replaced by other ones belonging in the same category. After the screening test, participants practiced a part of the LFPQ-J.

186

187 **2.3.3. Anthropometry**

188 Body mass and body composition were measured to the nearest 0.1 kg or 0.1 % using a digital
189 scale (TANITA MC780, Tanita Corporation, Tokyo, Japan) and height to the nearest 0.1 cm
190 using a stadiometer (YS-OA, As One Corporation, Osaka, Japan). Body mass index was
191 calculated as weight in kilogrammes divided by the square of height in metres. Waist
192 circumference was measured to the nearest 0.1 cm at the level of the umbilicus using a flexible
193 plastic tape. Blood pressure was measured using fully automatic blood pressure monitor (HEM-
194 907, OMRON Corporation, Kyoto, Japan).

195

196 **2.3.4. Three Factor Eating Questionnaire (TFEQ)**

197 The 51-item TFEQ is a self-assessment tool that measures eating behaviour, which consists of
198 three factors including cognitive restraint, disinhibition and hunger (Stunkard & Messick,
199 1985). The Japanese version of the TFEQ (Adachi, Fujii, & Yamagami, 1992) was used to
200 measure participants' eating behaviour traits in the present study. Although there are no clear
201 criteria provided, a score of ≥ 14 for cognitive restraint, a score of ≥ 14 for disinhibition and a
202 score of ≥ 7 for hunger are considered as elevated (Stunkard & Messick, 1985).

203

204 **2.3.5. Test day design and protocol**

A schematic representation of the test day protocol is shown in Figure 2. After the preliminary tests, participants reported to the laboratory twice at 08:30 after fasting for at least 10 hours (except water). Body mass and body composition were measured, and after a 5-min seated rest, blood pressure was measured. Food reward was measured using the LFPQ-J at 08:45 (Fasted state). Then, a standardised meal was served at 09:00 and participants were asked to consume the meal within 20 min. After a 30-min seated rest, food reward was evaluated again at 09:50 (Fed state). After more than one-week washout period, the participants repeated the same protocol as the first trial. Female participants conducted the trial during the follicular phase of the menstruation (within 10 days of menstruation) or took pills to align the hormone concentrations of oestradiol and progesterone in order to minimise the effect on appetite (Dye & Blundell, 1997).

Please insert Figure 2 near here.

2.3.6. Standardisation of dietary intake and physical activity

Participants weighed and recorded all food and drink consumed the day before the first trial (i.e., validation of LFPQ-J test) and refrained from drinking alcohol during this period. Participants replicated their dietary intake from the first trial in the second trial to ensure that dietary intake was standardised across trials. Food diaries were analysed by a registered

224 dietitian to determine energy intake and macronutrient content. In addition, participants were
225 asked to perform the same activity the day before each main trial and wore a uniaxial
226 accelerometer (Lifecoder-EX; Suzuken Co Ltd, Nagoya, Japan) on the hip to monitor their
227 daily activity objectively during this period. The accelerometer defined 11 levels of activity
228 intensity (0, 0.5 and 1-9), with 0 indicating the lowest intensity and 9 being the highest intensity.
229 A level of 4 corresponds to an intensity of ~3 metabolic equivalents (Kumahara et al., 2004).
230 Level of 1-3 corresponds to light physical activity level, 4-6 corresponds to moderate physical
231 activity level, 7-9 corresponds to vigorous physical activity level.
232
233 **2.3.7. Test meal**
234 The standardised meal consisted of a typical Japanese fish dish (made from grilled salmon), a
235 bowl of white rice, soup (made with seaweed, soybean paste, and deep-fried soybean curd) and
236 a bowl of salad (cabbage, tomato, and ham with a sesame dressing), a yogurt and an apple juice.
237 It provided 50 kJ (12 kcal) energy, 0.51 g protein, 0.31 g fat, and 1.74 g carbohydrate per
238 kilogramme of body mass in both trials. Mean macronutrient content was 29.8 ± 5.2 g protein,
239 18.0 ± 3.2 g fat, and 101.3 ± 17.8 g carbohydrate which provided 2.9 ± 0.5 MJ (699 ± 123 kcal)
240 energy (17% from protein, 23% from fat and 60% from carbohydrate). Participants were asked
241 to consume the entire test meal within 20 min, and the consumption time was recorded and
242 replicated in the second trial. Mean time to consume the standardised meal was 18.5 ± 2.0 min.

2.3.8. Calculations and statistical analysis

Data were analysed with IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, N.Y., USA) and GraphPad Prism 9 (GraphPad Software, Inc. La Jolla, California, USA). The absolute difference within the participants in LFPQ-J scores between the two testing occasions was analysed using Bland-Altman plots (bias, 95% limits of agreement and critical difference), and intra-personal correlation coefficients. The critical difference was set at two times the standard deviation of the difference between the first and second test days. A generalised estimated equation was used to examine between-test day differences for anthropometry measured in the morning, energy intake and physical activity level the day before each test. Statistical significance was accepted at the $< 5\%$ level. Results are reported as the mean ± standard deviation.

3. Results

3.1. Food image validation and final selection

Results from the food image database validation data are shown in Table 1. These food images were prioritised according to the results of recognition, frequency of eating, liking, and the perception of fat content and taste, considering the variety within each category. The four images from the highest priority were chosen as the standard photos for the LFPQ-J, and the

262 remaining were used as backups, with the highest priority being used first (Supplemental Table
263 1).
264
265 **Please insert Table** 1 **near here.**
266
267 **3.2. Experimental procedure using the LFPQ-J**
268 **3.2.1. Physical characteristics, anthropometry and eating behaviour**
269 The physical characteristics of the participants (mean ± standard deviation) were as follows:
270 age, 23 ± 2 years; height, 165.1 ± 7.9 cm; body mass, 58.5 ± 10.2 kg; body mass index, 21.3 ±
271 2.4 kg/m^2, body fat percentage, 20.7 ± 6.7 %, fat mass, 12.0 ± 4.3 kg, fat-free mass, 46.6 ± 9.5
272 kg, waist circumference, 74.6 ± 7.3 cm, systolic blood pressure, 107 ± 16 mmHg, and diastolic
273 blood pressure, 66 ± 8 mmHg. All variables did not differ between the first and second trials
274 (all for $p > 0.145$). Results from the Japanese version of TFEQ were as follows: cognitive
275 restraint, 7.7 ± 4.6; disinhibition, 6.2 ± 3.2; and hunger, 4.6 ± 3.0.
276
277 **3.2.2. Standardisation of energy intake and physical activity**
278 All participants reported that they consumed identical foods and drink between the first and
279 second trials. Mean self-reported energy intake for the day prior to each trial was 7.5 ± 2.3 MJ
280 (1796 ± 546 kcal). Energy intake equated to 14.1 ± 4.9 % (62.4 ± 22.7 g/day) from protein,

281 33.0 ± 8.9 % (66.1 ± 23.7 g/day) from fat and 53.0 ± 11.0 % (233.9 ± 88.5 g/day) from
282 carbohydrate.
283
284 The step counts recorded the day before the trials did not differ between the first and second
285 trials (9514 ± 6053 vs 9236 ± 5345 steps/day for the first and second trials, respectively, p =
286 0.636). Accelerometer recorded frequencies for light-intensity physical activity (53.3 ± 34.2 vs
287 52.1 ± 29.3 min/day for the first and second trials, respectively), moderate-intensity physical
288 activity (33.9 ± 24.5 vs 31.3 ± 20.9 min/day), vigorous-intensity physical activity (7.2 ± 13.3
289 vs 7.3 ± 12.7 min/day), moderate to vigorous-intensity physical activity (41.1 ± 31.5 vs 38.6 ±
290 27.8 min/day), and total physical activity (94.4 ± 59.2 vs 90.7 ± 50.3 min/day) did not differ
291 between the first and second trials (all for $p > 0.281$).
292
293 **3.2.3. Food reward**
294 Explicit liking, explicit wanting and implicit wanting of HFSA, LFSA, HFSW, LFSW, fat
295 appeal bias and taste appeal bias under the fasted and fed states are shown in Table 2. Four data
296 of the implicit wanting under the either fasted or fed states were invalid because the reaction
297 time were very short (i.e., shorter than 100 ms) or very long (i.e., longer than 8000 ms). These
298 data were excluded from the analyses for implicit wanting - data are therefore presented for 52
299 participants (fasted state, 23 men and 29 women; fed state, 22 men and 30 women).

3.2.3.1. Explicit liking

In the fasted state, 92.9 to 94.6 % of the data were plotted within the 95% limits of agreement (critical differences: 23.8 - 32.5), and intra-personal correlations were 0.69 - 0.79. In the fed state, 91.1 to 96.4 % of the data were plotted within the 95% limits of agreement (critical differences: 33.0 - 45.2), and intra-personal correlations were 0.57 - 0.72.

3.2.3.2. Explicit wanting

In the fasted state, 91.1 to 94.6 % of the data were plotted within the 95% limits of agreement (critical differences: 26.2 - 39.5), and intra-personal correlations were 0.58 - 0.76. In the fed state, 91.1 to 96.4 % of the data were plotted within the 95% limits of agreement (critical differences: 26.7 - 47.0), and intra-personal correlations were 0.56 - 0.75.

3.2.3.3. Implicit wanting

In the fasted state, 92.3 to 96.2 % of the data were plotted within the 95% limits of agreement (critical differences: 25.1 - 43.0), and intra-personal correlations were 0.70 - 0.81. In the fed state, 92.3 to 96.2 % of the data were plotted within the 95% limits of agreement (critical differences: 24.6 - 28.9), and intra-personal correlations were 0.68 - 0.83.

Please insert Table 2 near here.

3.2.3.4. Fat appeal bias

Bland-Altman plots for the fat appeal bias of explicit liking, explicit wanting and implicit wanting under the fasted and fed states are shown in Figure 3. In the fasted state, 94.2 to 96.4 % of the data were plotted within the 95% limits of agreement (critical differences: 35.1 - 42.4), and intra-personal correlations were 0.68 - 0.77. In the fed state, 92.3 to 94.6 % of the data were plotted within the 95% limits of agreement (critical differences: 19.1 - 28.1), and intra-personal correlations were 0.40 - 0.79.

Please insert Figure 3 near here.

3.2.3.5. Taste appeal bias

Bland-Altman plots for taste appeal bias of explicit liking, explicit wanting and implicit wanting under the fasted and fed states are shown in Figure 4. In the fasted state, 92.9 to 96.4 % of the data were plotted within the 95% limits of agreement (critical differences: 27.3 - 48.5), and intra-personal correlations were 0.65 - 0.77. In the fed state, 92.3 to 98.2 % of the data were plotted within the 95% limits of agreement (critical differences: 29.8 - 38.6), and intra-personal correlations were 0.58 - 0.80.

Please insert Figure 4 near here.

4. Discussion

The LFPQ is a computer-based procedure that evaluates liking, wanting and relative preferences for food. The main purpose of the present study was to culturally adapt and validate the LFPQ for a Japanese population (LFPQ-J). Of importance, the present study followed a standardised set of procedures for the cultural adaptation of the LFPQ-J and standardised diet and physical activity between the first and second trials of the laboratory validation of the LFPQ-J to increase the sensitivity and repeatability of the LFPQ-J scores (Oustric et al., 2020). The present study demonstrated that the selected food images during the developmental process were well perceived and accepted by Japanese adults. Moreover, as shown by the test-retest reliability analysis, the developed LFPQ-J is reproducible in both fasted and fed states.

In the cultural adaptation procedure of the development for the LFPQ-J, we created a database of food images for a wide range of age groups, and the subjective perceptions of foods of a sample of 200 Japanese adults in their 20s to 50s were surveyed. Throughout this process, the present study was able to establish 16 food images for the LFPQ-J, which were easy to recognise and familiar to the Japanese population, and met the inclusion criteria of the LFPQ

(Oustric et al., 2020). In fact, 97% of the participants in the present study were able to conduct the LFPQ-J using the selected 16 food images. This is important as food images that are less familiar may affect food choice (Leenaars et al., 2016).

The range of each LFPQ-J score observed in both fasted and fed states in each of the four categories in the present study was in accordance with a previous study and a recent review that have used versions of the British LFPQ (Finlayson et al., 2008; Oustric et al., 2020), and similar with the previous studies conducted in Saudi Arabia and Brazil (Alkahtani et al., 2016; Carvalho-Ferreira et al., 2019). Furthermore, the range of the intra-personal correlations in the present study was moderate to strong correlation (Landis & Koch, 1977), and obtained values are comparable to results reported previously (Dalton & Finlayson, 2014). Given that the standardisation of diet and physical activity prior to the baseline measurement of the LFPQ is an important procedure for a cross-over design (Beaulieu, Hopkins, Blundell, et al., 2017), our comparative findings between two trials may be influenced by each of these standardisation approaches. Therefore, these variables are needed to be carefully controlled when developing and validating a cultural adaptation of the LFPQ for future research.

For changes in the LFPQ-J scores from the fasted to fed states in the present study, the findings of both explicit liking and explicit wanting decreased for all food categories. For implicit

wanting, the findings of HFSA and LFSA decreased, whilst the findings of HFSW and LFSW increased in the fed state. Both fat and taste appeal biases for each of explicit liking, explicit wanting and implicit wanting were also altered in the fed state, indicating the reduced reward value of low fat relative to high fat, and increased reward value of sweet relative to savoury foods in the task. These overall post-meal changes were also observed in previous studies with other translated LFPQ versions (Alkahtani et al., 2016; Carvalho-Ferreira et al., 2019). It has been addressed that liking declined for all categories of food or mainly for savoury food while implicit wanting increased for sweet food after eating a mainly savoury test meal (Oustric et al., 2020). Participants in the present study consumed a typical Japanese set meal with a savoury taste. Therefore, similar post-meal changes in the explicit liking and wanting were expected (Oustric et al., 2020; Alkahtani et al., 2016; Carvalho-Ferreira et al., 2019). In addition, an unexpected observation was the increase in fat appeal bias for each of the explicit liking, explicit wanting and implicit wanting from the fasted state to the fed state. Previous research has shown that fat appeal bias decreases in the fed state in line with reduced energy needs (Thackray et al., 2020). Further, elevated hunger after overnight fast was associated with increased brain reward activity towards high versus low energy foods (Goldstone et al., 2009). As our standardised meal contained relatively low levels of fat, this may explain why the present findings showed an increase in fat appeal bias despite the reduction in hunger. Indeed, macronutrient- and lipid specific modulation of the reward system has recently been noted

(Berland, Small, Luquet, & Gangarossa, 2021; Perszyk et al., 2021).

In conclusion, the present study, using the culturally adapted and validated LFPQ-J, examined food reward before and after a standardised meal and demonstrated good individual consistency over two identical test days in Japanese young adults. Thus, the developed LFPQ-J is a sensitive and reproducible instrument for evaluating liking and wanting for food in Japanese adults.

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Ethical statement: The present study was approved by the institutional ethics committee (approval number: 2020–404) and conducted in accordance with the Declaration of Helsinki. This study was registered in advance with the University Hospital Medical Information Network Center (UMIN), a system for registering clinical trials (ID: UMIN000043924).

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Figure captions

Figure 1: The flow diagramme of participants during the study.

Figure 2: A schematic representation of the study protocol.

After a preliminary visit, each participant underwent two, one-day laboratory-based trials (i.e., the first and second trials). Participants reported to the laboratory at 0830 h. After anthropometry, food reward was evaluated using the Leeds Food Preference Questionnaire in Japanese (LFPQ-J) before and after a standardised meal at 0845 h (Fasted state) and at 0950 h (Fed state). After a greater than one-week washout period, the participants repeated the same protocol.

Figure 3: Bland-Altman plots for explicit liking, explicit wanting (n = 56) and implicit wanting (n = 52), of the fat appeal bias in the fasted (A) and fed (B) states.

These graphs illustrate the difference between the two trials (first and second) plotted against the means for each participant. Dotted line shows bias or mean differences between the two measures and dashed lines show 95% limits of agreement of the mean difference.

Figure 4: Bland-Altman plots for, explicit liking, explicit wanting (n = 56) and implicit wanting (n = 52) of the taste appeal bias in the fasted (A) and fed (B) states.

These graphs illustrate the difference between the two trials (first and second) plotted against the means for each participant. Dotted line shows bias or mean differences between the two measures and dashed lines show 95% limits of agreement of the mean difference.

Supplemental Figure 1: The final set of 16 food images for the LFPQ-J