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MEASURING FOOD PREFERENCE AND REWARD: APPLICATION AND CROSS-CULTURAL ADAPTATION OF THE LEEDS FOOD PREFERENCE QUESTIONNAIRE IN HUMAN EXPERIMENTAL RESEARCH

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Running title: Application and adaptation of the Leeds Food Preference Questionnaire

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ABSTRACT

Decisions about what we eat play a central role in human appetite and energy balance. Measuring food reward and its underlying components of implicit motivation (wanting) and explicit sensory pleasure (liking) is therefore important in understanding which foods are preferred in a given context and at a given moment in time. Among the different methods used to measure food reward, the Leeds Food Preference Questionnaire (LFPQ) is a well-established tool that has been widely used in the scientific field for over 10 years. The original LFPQ measures explicit liking and implicit wanting for the same visual food stimuli varying along two nutritional dimensions: fat (high or low) and taste (sweet or savoury/non-sweet). With increasing use of the LFPQ (in original or adapted forms) across different cultural and scientific contexts, there is a need for a set of recommendations for effective execution as well as cultural and nutritional adaptations of the tool. This paper aims to describe the current status of the LFPQ for researchers new to the methodology, and to provide standards of good practice that can be adopted for its cultural adaptation and use in the laboratory or clinic. This paper details procedures for the creation and validation of appropriate food stimuli; implementation of the tool for sensitive measures of food reward; and interpretation of the main end-points of the LFPQ. Following these steps will facilitate comparisons of findings between studies and lead to a better understanding of the role of food reward in human eating behaviour.

Keywords: Food reward, protocol, standard operating procedure, LFPQ, liking, wanting

Abbreviations: LFPQ: Leeds Food Preference Questionnaire, HFSA: high-fat savoury, LFSA: low-fat savoury, HFSW: high-fat sweet, LFSW: low-fat sweet, VAS: Visual Analogue Scale

INTRODUCTION

Food is a highly accessible reward in our current obesogenic society. As a species of omnivores, people’s food choices play a key role, alongside portion size, energy density and meal timing, in contributing to energy intake (Berthoud, Lenard, & Shin, 2011; Lowe & Butryn, 2007). Reward is a biopsychological process embedded in the brain that interacts with the food environment (e.g. food properties, palatability, availability, social habits) and the internal milieu (e.g. cognition, metabolism) (Berthoud, Munzberg, & Morrison, 2017). Rather than a unitary construct, food reward consists of distinct sub-components broadly conceptualised as "liking" versus "wanting" that have been shown to have separate neural representations (Berridge, Robinson, & Aldridge, 2009). Particularly in the context of obesity and disordered eating, the two separate processes of liking and wanting may be key variables to measure and track (Finlayson & Dalton, 2012).

A variety of methods have been used to measure food reward in humans, which can lead to difficulties when comparing between studies (Pool, Sennwald, Delplanque, Brosch, & Sander, 2016). The most common measures of food reward are self-reported food liking (the explicit hedonic experience) (Pool et al., 2016), self-reported desire to eat a specific food (the explicit desire to eat) (Berridge, 2009) and motivational food wanting (the indirectly inferred or implicit motivation to eat a specific food) (Berridge, 2009). Explicit liking and desire to eat are most commonly measured through ratings scales such as visual analogue scales (VAS). Two main indirect approaches have been proposed to measure the construct of implicit wanting. One is the hypothetical or actual effort expended to obtain a food (i.e. motivation assessed by memory games (Lemmens et al., 2010), grip force tasks (Ziauddeen et al., 2012), relative reinforcing value tasks (Epstein, Leddy, Temple, & Faith, 2007) or willingness to pay (Brunstrom & Rogers, 2009)). The other is the reaction time of responses to a food stimulus presented either subliminally or supraliminally, often relative to an alternative or control (i.e. attentional bias measured by visual-probe task (Brignell, Griffiths, Bradley, & Mogg, 2009), Stroop task (Nathan et al., 2012), and forced choice task (Gibbons, Finlayson, Dalton, Caudwell, & Blundell, 2014)). Brain responses to foods are also used as an inference of reward from differences in neural activation (BOLD signal) in reward regions following exposure to food stimuli (Rosenbaum, Sy, Pavlovich, Leibel, & Hirsch, 2008).

Reliable and valid measures of reward are needed to consistently quantify and report food reward in different contexts. The Leeds Food Preference Questionnaire (LFPQ) is a computer-based platform that measures with a single instrument, separate aspects of food reward including explicit liking and wanting, relative preference (food choice) and implicit wanting for food categories consisting of common foods in the diet. The original LFPQ (G. Finlayson, N. King, & J. Blundell, 2007a) assesses how participants respond to binary dimensions of fat and sweet taste represented by four food categories (i.e. high-fat savoury (HFSA), low-fat savoury (LFSA), high-fat sweet (HFSW) and low-fat sweet (LFSW)). The LFPQ has been shown to be sensitive to individual differences in eating behaviour traits (Dalton, Blundell, & Finlayson, 2013; Finlayson, Bordes, Griffioen-Roose, de Graaf, & Blundell, 2012). The LFPQ has been validated against actual food selection and consumption (Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; Griffioen-Roose et al., 2011) and is a good predictor of actual food choice and intake in both laboratory and free-living settings (Dalton & Finlayson, 2014; French et al., 2014).

While the current and original LFPQ includes 16 food photographs, four food images for each of the four food categories, other versions have used five images per category (Finlayson, King, & Blundell, 2008) and two per category (Charlot, Malgoyre, & Bourrilhon, 2019). Adaptations of the LFPQ have included dimensions of protein (Griffioen-Roose et al., 2011; Karl et al., 2018), fruits/vegetables and snacks (G. Finlayson, N. King, & J. Blundell, 2007b), and alcoholic/soft drinks in high or low calorie form (unpublished data). The LFPQ has also been used in different appetite-related contexts such as high altitude (Aeberli et al., 2013), elderly care homes (Van der Meij, Wijnhoven, Finlayson, Oosten, & Visser, 2015), eating disorder clinics (Cowdrey, Finlayson, & Park, 2013; Dalton & Finlayson, 2014), sleep laboratories

(McNeil et al., 2017), bariatric surgery wards (Redpath et al., 2018), or anti-obesity/diabetes drug trials (Blundell et al., 2017) and is now translated linguistically into 16 languages including Tamil (Ranasinghe et al., 2018), Arabic (Alkahtni, Dalton, Abuzaid, Obeid, & Finlayson, 2016), Mandarin Chinese (Zhou et al., 2019), Estonian (Arumäe, Kreegipuu, & Vainik, 2019) and Norwegian (Martins et al., 2017). The widespread use and adaptation of the LFPQ creates a need to provide a uniform procedure and best practice recommendations to develop and implement reliable cultural adaptations, improve data quality and facilitate comparison with other studies.

PURPOSE

This paper aims to develop a standardized set of procedures to facilitate the consistent assessment of food reward using LFPQ in various cultural and scientific contexts. This protocol goes beyond simple linguistic translations and proposes a method for cultural adaptation and best practice recommendations for use in research and clinical assessments. The long-term goal is to improve the sensitivity and comparability of the measure between studies by improving the consistency of its application. In practice, this protocol intends to be easy to follow and give a better understanding of the task.

Part 1: Leeds Food Preference Questionnaire: description of the task and its application

1.1 Summary of the LFPQ procedure

The LFPQ consists of two sub-tasks that require interactions from the participant. One task involves an explicit evaluation of food images from an array of pre-validated photographs using VAS. The other requires a rapid choice to be made between paired combinations of the food images from different categories. The order of tasks is either randomised or counterbalanced within the programme and the total procedure lasts approximately 6-8 min. The food pictures in the LFPQ are pre-validated such that the macronutrient content of the foods define their categories (high-fat: >40% energy from fat, low-fat: <20% energy from fat, while matching protein content as possible). The perceived attributes of the pictures are also tested as detailed in part 2 (e.g. food pictures that are well-recognized, frequently eaten, adequately liked, correctly identified as sweet/savoury, low- or high-fat, and suitable for the intended time of day). The LFPQ can be programmed using different software and has mainly been used with E-Prime (Psychology Software Tools, Inc). Effective administration of the LFPQ requires a standard operating procedure and this is presented in part 1.

1.2 Explicit VAS responses

The explicit task includes 100-unit VAS that measures explicit liking and explicit wanting for the food images. Single food images are randomly presented to the participant who is required to rate according to "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) (see fig 1). The two questions are not randomised but counterbalanced and have different font colours to better discriminate and comply with the task. Another compliance feature is the re-centering of the mouse cursor away from the VAS after each trial. To improve reliability, the test begins with four practice trials (that do not contribute to the test outcomes) to prepare participants for the procedures of the task, and a "rest" screen is inserted in the middle of the task to provide participants with an optional break from the continued demand of the task. Once all the foods have been rated according to both questions, a screen appears either to notify the participant that the task has ended or to prepare the participant for the forced choice task.

Figure 1: Representation of the single foods instructions with (A) explicit liking (blue) and (B) explicit wanting (red)

1.3 Forced choice and implicit responses

The forced choice task presents the participant with a series of food image pairs and the instruction "Which food do you most want to eat now?". After four practice trials to familiarise participants, food pairs are presented such that all food images from one category are presented with each food from the alternative categories. The task presents all 96 possible pairs in random order. A rest screen is included after every 32 trials to alleviate response fatigue. Participants are instructed to select as quickly as possible the food they want to eat the most at that moment (see fig 2). To improve compliance, a central fixation cross on a white background is presented before each trial for 500ms. The forced choice task requires more sustained attention from the participant than the single food task and those who have difficulty complying (such as children or with impairment) should be encouraged to make use of the rest screens. Once all pairs have been presented, a screen appears either to notify the participant that the task has ended or to prepare the participant for the explicit VAS task.

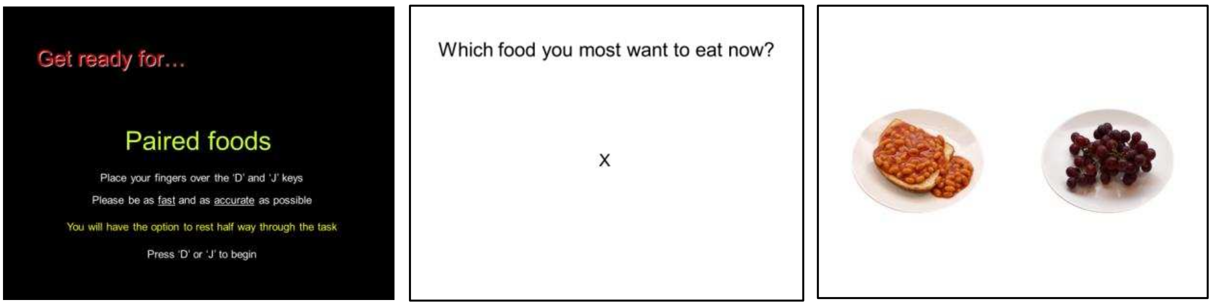

Figure 2: Representation of the paired foods instructions and the implicit wanting trials of the LFPQ

1.3.1 Calculation of the implicit wanting score

For each food category, the frequency of choice and non-choice, and the reaction time of each trial is recorded. The measure of implicit wanting is calculated by a combination of these metrics with a frequency-weighted algorithm (FWA) that accounts for both the speed and frequency of choosing or avoiding a food in each category (see equation). The score of one category is therefore relative to the selection or non-selection of the other categories.

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

Formula legend: I_A = Implicit wanting for category A; N_{choice} = number of times category A was selected; $N_{non\text{-}choice}$ = number of times category A was not selected; $\bar{t}$ = mean of all reaction times.

1.4 Understanding the measurements

1.4.1 Explicit liking and wanting

Explicit liking and wanting scores are simple to interpret as they use a standard 100-unit VAS rating. The higher score indicates a greater explicit liking or explicit wanting for the specific food. These results are computed by category (e.g. HFSA, etc.) and can be interpreted as the absolute explicit food reward for each food category (for example explicit liking or wanting for HFSW). Explicit liking and wanting have been reported in different patient groups such as in anorexia nervosa (Cowdrey et al., 2013), in binge eating (Dalton et al., 2013; Finlayson, Arlotti, Dalton, King, & Blundell, 2011), or in healthy weight (Griffioen-Roose et al., 2010).

1.4.2 Implicit wanting

Due to the design of the forced choice task, implicit wanting is a relative measure of motivation for one food category compared to the alternative categories. To measure implicit wanting, reaction times for all responses are covertly recorded and used to compute mean response times for each food category after adjusting for frequency of selection. Implicit wanting score is influenced by both selection (positively contributing to the score) and non-selection (negatively contributing to the score) of a food category. Therefore, a positive score indicates a more rapid preference for one category over the other and a negative score indicates the opposite. A zero score indicates that the category is equally preferred to the other categories. Implicit wanting for one category of food should not normally be interpreted independently from the others. Previous computations for the implicit wanting measure have included mean raw reaction time for each category and 'D-score' calculated from the difference between reaction time of the target category from the mean of the alternative categories divided by the pooled standard deviation from all trials. While these different iterations of implicit wanting are highly correlated, some caution should be taken when comparing results between studies. Future development of the LFPQ could examine the weighting of reaction time relative to choice-frequency in the calculation for implicit wanting.

1.4.3 Food choice and appeal bias

For a simpler measure of food choice or relative preference, the mean frequency of selection for each food type can be used. In the case of less complex research designs that do not require the analysis of all individual food categories, it is possible to compute a composite "appeal bias" for each endpoint of the LFPQ. Mean low-fat scores can be subtracted from the mean for high-fat scores to provide a "Fat Appeal Bias" for high-fat versus low-fat food for each outcome (explicit liking, explicit wanting, implicit wanting, relative preference). In the same way, a "Sweet Appeal Bias" can be calculated and represents the bias for sweet compared to savoury/non-sweet food. The "Appeal Bias" can be calculated for implicit wanting, liking and food choice. The advantages of using the appeal bias variables over separate category variables are they provide a single outcome for use in complex multivariate designs; the interpretation of explicit liking and implicit wanting scores are also more directly comparable. The disadvantage of using the appeal bias outcomes is that they are not suitable for study hypotheses concerning taste-fat interactions. Appeal bias scores have been previously reported in different contexts such as sleep restriction (McNeil et al., 2017), exercise (Martins et al., 2017), following high-fat or high-carbohydrate meals (Hopkins, Gibbons, Caudwell, Blundell, & Finlayson, 2016), or chewing gum (Bobillo et al., 2016).

1.5 Good practice in the laboratory or clinic

It is possible to compare measures of food reward between studies. However, caution must be taken as several contextual factors may affect food reward measurements (but this is also true for non-LFPQ measures of reward). Measures should preferably be compared when taken at the same time of day, same physiological state (e.g. fed vs hungry), and in response to similar or comparable food stimuli (Oustric, Gibbons, Beaulieu, Blundell, & Finlayson, 2018). Biological (e.g. fat mass), psychological (e.g. eating behaviour traits), and cultural factors (e.g. social habits) should also be taken into account and controlled for when comparing measures of food reward. It is therefore recommended to validate the LFPQ in the same target population as your study.

Table 1 gives an example of expected values for the different LFPQ outcomes for a specific population.

Table 1: Typical scores of the four averaged food categories for a population of women with overweight and obesity

Food reward components	Range	Typical mean ±SD[a] or range[b]	
		Hungry	Fed
Explicit Liking	[0-100]	57.18 ± 20.02	28.37 ± 22.53
Explicit Wanting	[0-100]	51.33 ± 21.06	16.24 ± 16.65
Implicit Wanting	-100-100[c]	-13.1 to 20.19[b]	-38.77 to 27.06[b]
Food Choice	[0-48]	24.00 ± 10.21	24.00 ± 8.48

This example is based on N=46 UK resident women with a mean BMI of 29.17 (range: 25.43 – 34.57) kg/m^2 from the baseline measurements of a dietary weight loss clinical trial (NCT03447600). These results are similar with those published in other countries (Alkahtni et al., 2016; Carvalho-Ferreira et al., 2019) for individuals with a wider BMI range. [a]Results are computed on the mean of the four food categories at the individual level in order to obtain typical scores. [b]As implicit wanting is a forced-choice between categories, the mean of the four categories at the individual-level equals to 0; therefore, the range is reported. [c]Due to reaction times values there is no fixed min-max value for implicit wanting.

The administration of the LFPQ involves input from the researcher during image screening and test days.

1.5.1 Screening

Before executing the task in itself, it is important to give the opportunity for participants to screen and replace the validated food images included in the task. This is to improve internal validity and justified on the basis that using an alternative validated food from the same category will yield better responses than using a fixed food that is avoided. The screening process can be completed before first administration of the LFPQ or ideally on a prior separate visit. The steps are as follows:

1. Show the 16 core food stimuli used in the study to the participant in sequence
2. Ask participant to name each food aloud and note if there are any items they: a) would never/rarely eat; or b) don't know or recognise.
3. Show the participant pre-validated replacement options from the same food category and agree on the most appropriate replacement food image (old-new).

1.5.2 Test days

It is recommended that the LFPQ task is administered in an environment free from external distractions, such as a private room or laboratory testing cubicles. Once in the room, make sure the participant switches off any electronic devices that could distract them during the task.

1. Explain to the participant what to expect from the task: "You are going to complete a computer task that measures your food preferences"
2. Read aloud the instructions on the screen and practice a few trials of each task at least once until the participant is familiar with what they are required to do. Stay with the participant until they feel they have practiced enough and answer any questions. Let them know they can practice each task as many times as they like until they are familiar with the task.
3. Explain that in the explicit rating task, the questions will change and that in the paired

food task they should respond as quickly as possible and that they should not think too much before making a choice. For both tasks mention that the participant should "think about the food in itself and imagine you can have as much or as little as you want".

4. Leave the participant alone to complete the LFPQ. Allow 10 minutes (the task takes 6-8 minutes) to complete before returning.

5. Ask participant if there were any problems during the task. Do they have any questions?

Part 2: A standardized set of procedures for cultural adaptation of the LFPQ

The cultural adaptation and implementation of the LFPQ should be considered carefully. These steps include 1) appropriate choice and validation of the food pictures; 2) accurate translation of the task; and 3) validation study design considerations. Pilot testing is also an important step to make sure that the principles are transferred into practice.

Table 2 presents the main steps and methods to develop a cultural adaption of the LFPQ

Table 2: Best practice and methods to develop a cultural adaption of the LFPQ

	Steps to achieve	Methods proposed
SELECTION AND VALIDATION OF THE FOOD PICTURES	**1. Selection of food pictures** a. Ready to eat foods b. Limit the number of food items c. Recommended/usual portion size d. Appropriate to the time of day at the measurement e. Appropriate to the culture and habits of the targeted population f. Diversity of food category within each group g. Homogeneity between the pictures **2. Selection of food pictures according to their macronutrient content:** a. High-fat: >40% energy from fat b. Low-fat: <20% energy from fat c. Match protein content as possible	1. Use national cohort data to select commonly consumed food items. 2. Create food pictures and characterise their macronutrients content using food database.
	3. Validation of the food pictures that are: a. Correctly recognized b. Culturally appropriate c. Frequently consumed d. Recognised as palatable	- Validation by online questionnaire in the targeted population
	e. Correctly perceived as belonging to the four food categories (HFSW, LFSW, HFSA, LFSA)	- Cluster analysis from the questionnaire' answers
TRANSLATION OF THE TASKS	**4. Translation of liking and wanting constructs in the targeted population** a. Test the understanding of the questions and of the difference between the construct liking vs wanting, and sweet vs non sweet	- Pilot testing, and translator - Validation by online questionnaire (e.g. How would you explain this concept? What does this mean for you?)
DESIGN OF THE VALIDATION STUDY	**5. Validation of the task depending on the research question** a. Validation of the sensitivity and accuracy of the task b. Validation of the reliability of the task	- Can the dissociation between liking and implicit wanting pre to post food consumption (hungry to fed) be replicated?

2. STEP 1: Selection and validation of the food pictures - Cultural/perceptual characteristics of the food pictures

Creating an appropriate array of food images is the first step to developing a cultural adaptation of the LFPQ. Food choices are culture-specific and therefore food pictures should be carefully selected to be common in the local diet, easily recognized, well-accepted and clearly identifiable as predominantly savoury or sweet and low or high in fat (see next section on validation of images). We propose the following selection criteria for candidate food images in the task, shown in Table 3.

Table 3: Selection criteria for judging the perception of the food pictures

Criteria	Description
Ready to eat form	Avoid cooking/preparation bias such as raw or packaged items
Limited variety	Reduce diversity of food items in one image
Typical presentation and portion size	Promote familiarity and limit portion size effect
Appropriate to the time of the day of the measurements	No strongly associated morning, afternoon or evening foods
Appropriate to the culture and habits of the targeted population	Recognized, culturally acceptable, usually eaten, palatable
Diversity of food within each category	Good representation among foods while staying realistic
Homogeneity of the image background	Usual plate/bowl, same light, consistent or cropped background

The food images should be verified by a panel preferably consisting of nutritionists, dieticians or health professionals to ensure the criteria are met. In terms of number of food pictures, 16 food pictures are needed and at least one or two substitute/alternative food pictures for each category are recommended to match individual preferences (in case of religious or personal food avoidance). It is therefore recommended to select a larger number of pictures to validate as the process of validation can be quite stringent. Figure 3 gives an example of an array of pictures appropriate to the British culture that have followed this protocol.

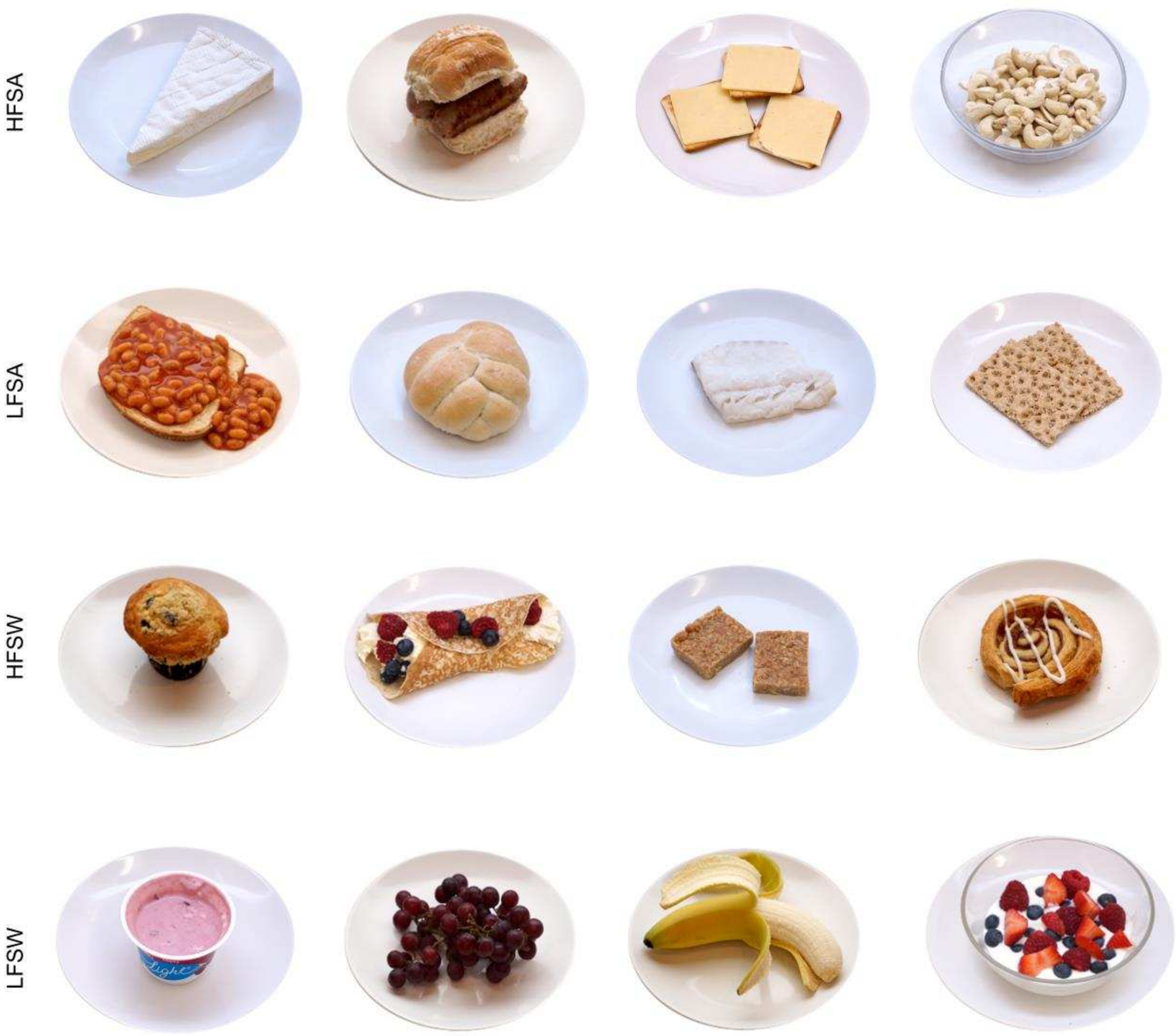

Figure 3: Example set of pictures from a British LFPQ. High-fat savoury (HFSA): brie, sausage sandwich, cream crackers with cheese, cashews; low-fat savoury (LFSA): beans on toast, bread roll, white fish, rye crackers; high-fat sweet (HFSW): blueberry muffin, crepe with cream and fruits, flapjack, cinnamon swirl; low-fat sweet (LFSW): Light cherry yogurt, red grapes, banana, yogurt and berries.

2. STEP 2: Nutritional characteristics of the food pictures

The following steps aim to characterise each food item selected according to its macronutrient content. This is to ensure that the chosen foods have a nutrient composition adequate for their categories and to minimise imbalanced macronutrient composition. The main nutrient criteria aims to match the perception of fat with the actual fat content. In this example, the high-fat categories (HFSA and HFSW) contain predominantly more than 40% of their energy from fat whereas the low-fat categories (LFSA and LFSW) contain less than 20% of their energy from fat. A secondary criterion is to match as much as possible the protein level while respecting the natural variation between foods. Often it is possible to match at least the savoury groups (relatively high protein level) and the sweet (relatively low protein level). It is important that the food chosen reflect the reality of what is regularly and culturally eaten in the targeted population. As an example, table 4 gives the nutritional composition of a British LFPQ shown in figure 3.

Table 4: Nutritional composition of food pictures from a British LFPQ

	Food	Kcal/100g	% Pro	% Carb	% Fat
HFSA	Sausage sandwich, white roll	278.88	24.36	22.80	50.08
	Brie	291.00	25.15	0.52	74.23
	Cashews	642.00	13.71	13.79	70.23
	Cream crackers with cheese	408.67	18.48	25.96	53.13
MEAN		**405.14**	**20.42**	**15.77**	**61.92**
LFSA	Beans on toast	122.29	19.11	66.46	4.63

	Bread roll	258.00	13.18	69.77	9.77
	White fish	98.00	89.80	1.91	11.94
	Rye crackers (plain)	350.00	9.71	71.68	4.37
MEAN		**207.07**	**32.95**	**52.45**	**7.68**
HFSW	Blueberry muffin	367.00	5.45	44.14	46.35
	Cinnamon swirl pastry	445.00	4.94	37.67	53.80
	Crepes with cream & berries	262.64	4.58	16.14	79.26
	Flapjack	435.00	4.87	48.28	41.38
MEAN		**377.41**	**4.96**	**36.56**	**55.20**
LFSW	Red grapes	66.00	2.42	87.50	1.36
	Yogurt and berries	64.13	17.80	44.04	32.23
	Banana	103.00	4.66	83.74	4.37
	Light cherry yogurt	51.00	30.59	59.56	1.76
MEAN		**71.03**	**13.87**	**68.71**	**9.93**

HFSA: high-fat savoury, LFSA: low-fat savoury, HFSW: high-fat sweet, LFSW: low-fat sweet; % Pro: Percentage of total energy from protein, % Carb: percentage of total energy from carbohydrate, % Fat: percentage of total energy from fat

2. STEP 3: Validation of the food pictures

To validate food stimuli in the food database we recommend a survey-style questionnaire that can be distributed electronically or completed in person by members of the target population, balanced for gender and matched as close as possible for age. The aim of the survey is to select the best food pictures that are well-recognized, frequently eaten, adequately liked, correctly identified as sweet/savoury, low- or high-fat, and suitable for the intended time of day. Indeed, the accuracy of the test depends on the quality of the selection of the food pictures. If the food is not familiar or not correctly recognized it will affect the responses on the task. In the survey, each food picture can be presented individually and we propose eight main questions and criteria to qualify their suitability (see table 5)

The understanding of the question wording needs to be pilot tested by natives of the population. In order to avoid bias, participants should be removed from the analysis if they do not live in the target country or are nutritionist/dietitians. The suggested criteria have been defined according to the mean of the responses and are similar to the one used in the cultural adaptation performed in Brazil (Carvalho-Ferreira et al., 2019).

Table 5: Questions and proposed criteria for judging the adequacy of the food pictures

Criteria	Questions (answers)	Proposed cut-offs
Recognition	"Please name the food image?" (free-text response)	Correctly recognized (>80% of the participants name the food correctly)
Frequency	"How often do you consume this food?" (6-point scale: never, once a year, every few months, once a month, once a week, almost every day)	Habitually consumed (> 2 or eat more than several times a year can be a proxy for a usually consumed food)
Liking	"How pleasant does this food typically taste?" (100-mm scale from not at all pleasant to extremely pleasant)	Liked (>60 can be considered as a high liking when compared with the liking mean)
Food categories	"Is this food more sweet or savoury?" (100-mm scale from sweet to savoury); "Is this food low or high in fat?" (100-mm scale from low in fat to high in fat)	Correctly recognized as sweet vs savoury (sweet if the mean value of the 100mm VAS is <40 and savoury if >60, similarly a food is considered low-fat if the mean value of the 100mm VAS is <40 and high-fat if >60.)
Time appropriateness	How appropriate is it to consume this food in the morning/afternoon/evening?" (100-mm scale from not at all appropriate to extremely appropriate).	Appropriate time (>60 on the VAS is considered to be appropriate for the specific time-of-day).

VAS: Visual analogue scale

Food pictures are considered valid if they match the proposed cut-offs (table 5). However, it can be difficult to find LFSA foods that are liked and time-of-day appropriate, as this category is generally less liked than the others. It is therefore recommended to prioritise the foods that are eaten throughout the day. As an example of results validating the adequacy of the pictures, Table 6 presents the result from a survey performed in Leeds (UK) in 135 individuals (mean age 26 years, 66% female) The mean results of the criteria (e.g. recognition, frequency, etc.)

match the guidelines and cut-offs proposed As an example, a hierarchical clustering was performed in R using the 135 responses from the previous survey. Euclidean distance and Ward's methods were used. The number of clusters was determined using the dendrogram and the silhouette plot that showed no negative values attesting the consistency of the cluster. Figure 4 represents graphically the results of the hierarchical clustering on a scatter plot, where all the foods are plotted according to their scaled mean rating on fat and sweet. This figure shows that the foods are clustered in four different groups that are clearly distinguishable as HFSA, LFSA, HFSW and LFSW. In conclusion the validation of the food images for this example British LFPQ illustrates how to validate the nutritional composition, the perception of the pictures and how to achieve realistic food items that are well-accepted in the diet.

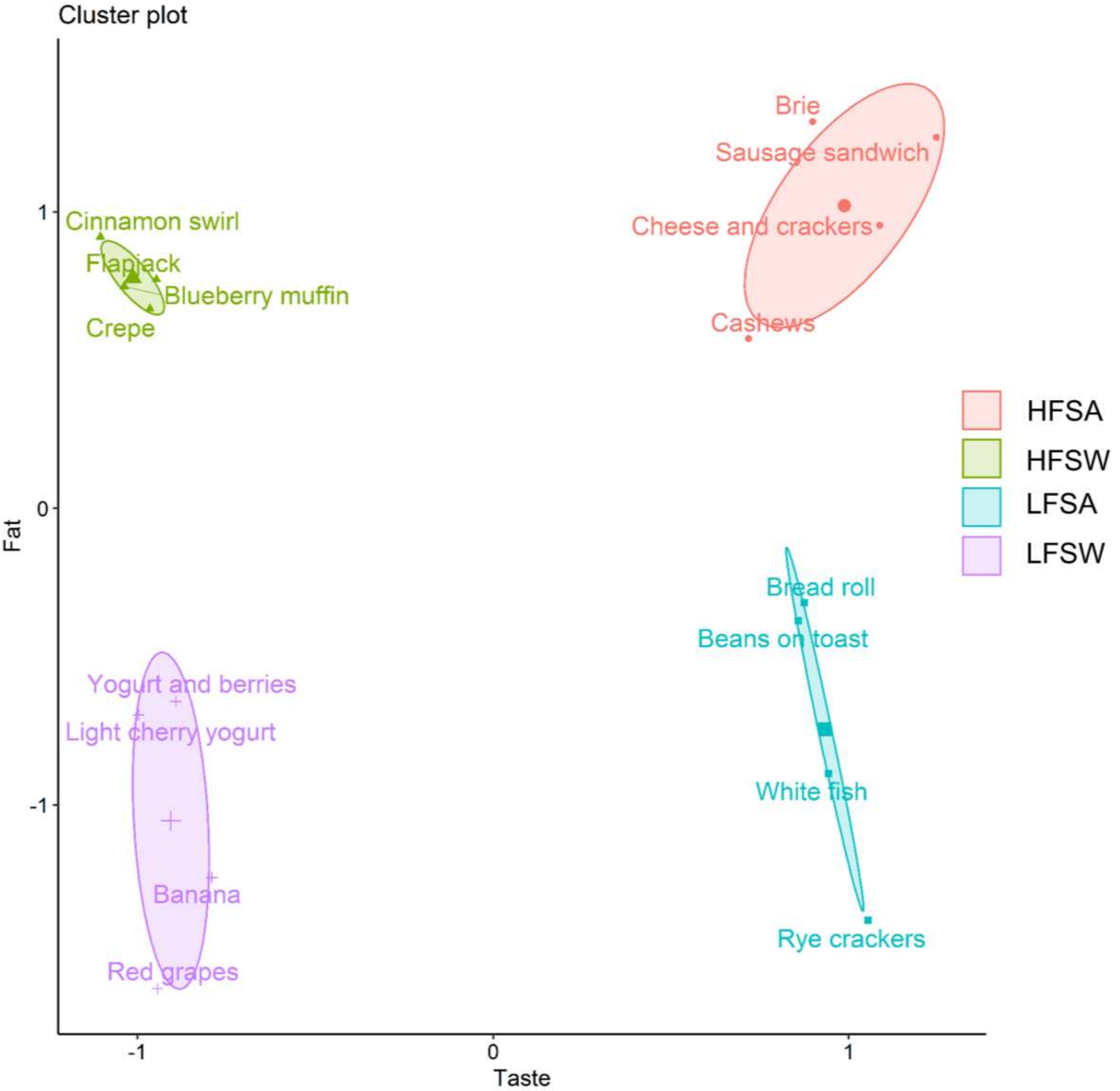

Figure 4: Scatter plot depicting the results of the hierarchical clustering by taste and fat from a British LFPQ. Mean results of the survey for taste and fat have been scaled and the foods have been projected according to their new fat and taste coordinates. Positive ratings represent savoury taste or high-fat, respectively. Smaller points represent the foods and larger points depict the centre of the cluster. The smaller the ellipse of the cluster, the more homogenous the cluster (e.g. HFSW). The further the food are from zero, the more separate are the clusters. This scatter plots attests of four distinct groups of food and allows to spot which food are closer to other clusters. Plot performed on R version 3.5.1 (R Core Team, 2013)

using factoextra v1.0.5 package and enhanced hierarchical clustering (see SUPPLEMENT for the code).

Table 6: Results of the validation of the food images from a British LFPQ (n=135)

	Food	Recognition	Frequency	Liking	Taste	Fat	Morning	Afternoon	Evening
HFSA	Sausage sandwich	100.00	2.76	65.84	92.71	80.79	77.06	66.73	52.87
	Brie	93.55	2.99	66.54	80.44	82.10	30.52	71.69	82.91
	Cashews	90.53	3.31	65.56	74.08	64.05	45.26	73.36	75.44
	Cream crackers with cheese	100.00	3.01	68.13	87.10	73.47	30.82	70.93	82.01
MEAN		**96.02**	**3.02**	**66.52**	**83.58**	**75.10**	**45.91**	**70.68**	**73.31**
LFSA	Beans on toast	99.09	3.36	68.78	79.00	40.54	82.92	79.29	69.82
	Bread roll	100.00	4.12	69.79	79.62	42.05	76.37	86.06	75.18
	White fish	88.70	3.34	60.00	82.03	27.84	22.43	66.36	82.08
	Rye crackers	91.84	2.48	36.04	85.92	15.63	58.67	74.85	59.34
MEAN		**94.91**	**3.32**	**58.65**	**81.64**	**31.52**	**60.10**	**76.64**	**71.60**
HFSW	Blueberry muffin	97.56	2.68	73.52	12.18	68.39	59.51	70.80	59.16
	Cinnamon swirl	97.50	2.19	68.13	9.83	72.52	70.95	64.21	44.92
	Crepe with cream and fruits	99.15	2.21	76.11	14.74	66.52	76.19	63.42	56.81
	Flapjack	96.81	2.83	77.14	15.38	68.97	54.48	76.72	62.23
MEAN		**97.76**	**2.48**	**73.72**	**13.03**	**69.10**	**65.28**	**68.79**	**55.78**
LFSW	Red grapes	100.00	4.45	85.30	15.48	9.95	80.74	87.66	83.29
	Yogurt and berries	87.88	3.57	76.22	17.29	33.83	86.04	66.06	60.62
	Banana	100.00	4.53	65.79	20.87	19.18	91.21	88.82	74.02
	Light cherry yogurt	100.00	3.59	70.24	13.62	32.72	88.15	75.90	65.52
MEAN		**96.97**	**4.03**	**74.39**	**16.82**	**23.92**	**86.54**	**79.61**	**70.86**

2. STEP 4: Translation of the task

With the linguistic translation of the LFPQ, we recommend working in collaboration with native speakers from the target country. It is important to achieve an understanding of the specific phrases used to capture the meaning of the explicit constructs in the LFPQ. It is also worth checking the native understanding of the dichotomous dimensions of sweet vs savoury food, if the term ‘savoury’ does not translate well in the home region then the alternative dimension of sweet vs non-sweet food can be used. Conducting back-translation may further strengthen the validity of the translated task.

2. STEP 5: Validation of the task

As a psychometric task, the LFPQ is concerned with the quality, validity, standardization and reliability of its measurements (Aldridge, Dovey, & Wade, 2017). The present protocol aims to assure the quality and standardization of both food images and application of the tool. The last step of the protocol tests the validity and reliability of the task to make sure the measures are accurate, meaningful and stable when repeated over time.

2.5.1 Validation of the sensitivity and accuracy of the task

The validation of a new cultural adaptation will depend on the research question and on the population targeted. One suggestion is to apply the LFPQ before and after an ad libitum lunch test meal in a controlled environment after a ~3-hour fast following a standardized breakfast. This design allows firstly to assess the effect of altered physiological states (hungry vs fed) on food reward. Secondly, this design enables the study of the relationship between food reward in the hungry state on subsequent food intake and whether components of food reward can predict actual food selection or energy intake. It has been demonstrated that the LFPQ is responsive to manipulation of hunger state which is consistent with alliesthesia (Finlayson et al., 2007a) and sensory specific satiety/habituation (Finlayson et al., 2008; Griffioen-Roose et al., 2010). After a mainly savoury test meal, liking and implicit wanting dissociate from hungry to fed state with liking decreasing for all categories of food or mainly for savoury food while implicit wanting increases for sweet food. These results have been replicated in countries representing different cultures such as Brazil (Carvalho-Ferreira et al., 2019)and Saudi Arabia (Alkahtni et al., 2016).

2.5.2 Validation of the reliability of the task

To assess the reliability of the task (i.e. the degree to which results are consistent over time) a test-retest analysis can be performed. This should be carried out on all the outcomes of interest (i.e. liking, implicit wanting and food choice) and for all the food categories (i.e. HFSW, LFSW, HFSA, LFSA). It is suggested to repeat the measures under the same condition at least two times and a week apart with no other varying parameters (e.g. performing the LFPQ at hungry state after the same preload a week apart in the same sample). Measuring the magnitude of the agreement between repeated measures can be done using absolute difference in scores such as Bland-Altman plots (Bland & Altman, 1986) and intraclass correlation coefficient (ICC) (Koo & Li, 2016). Bland-Altman plots graphically depict any systematic bias in the task, by plotting the difference scores of two measurements against the mean for each subject. ICC estimates and their 95% confidence intervals should be reported accompanied with the software used, the model (two-way mixed effect) the number of measurements (e.g. k=2) and the absolute agreement (Aldridge et al., 2017; Koo & Li, 2016). As an example, figure 5 presents Bland-Altman plots for the four categories of liking in 39 participants from a study conducted in our laboratory (Beaulieu, Hopkins, Blundell, & Finlayson, 2017). The mean differences between week 1 and 2 are small (i.e. the bias is approaching zero) the limits of agreement are not too wide (less than 28 out of 100) and only one participant is outside the limits of agreement line indicating a good reliability of the task for liking. For other examples of Bland-Altman plots (i.e. explicit wanting, implicit wanting and food choice) see the supplementary material.

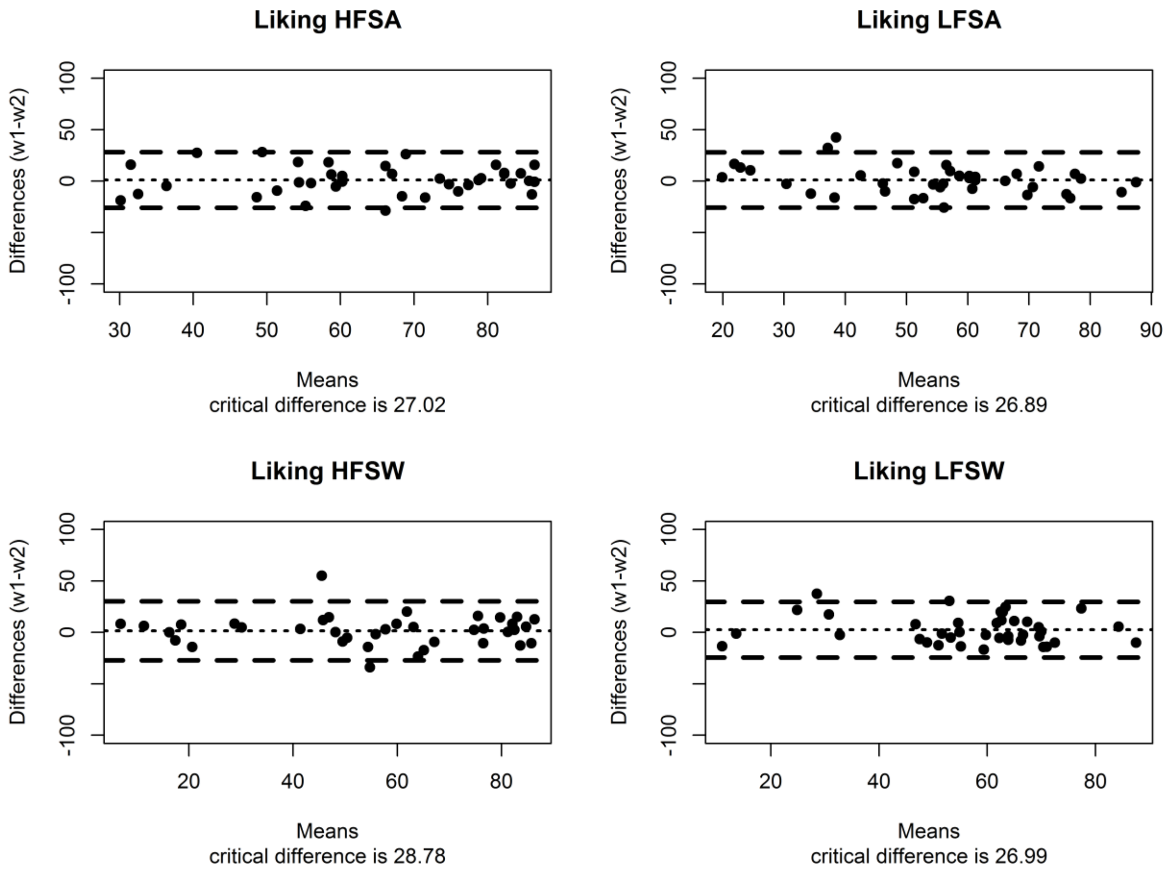

Figure 5: Bland-Altman plot for liking in the hungry state from a British LFPQ (n=39). These graphs illustrate the difference between the 2 measures (week 1 and week 2) plotted against the means for each participant. Dotted line = Bias or mean differences between the 2 measures; dash lines = 95% limits of agreement of the mean difference. The critical difference is “two” times standard deviation of the difference between the 2 measures (half of the limits of agreement). The bias (dotted line) should be close to zero and the limit of agreement narrow to support the reliability of the task. Participants should be evenly distributed along the means. Plot performed on R version 3.5.1 (R Core Team, 2013) using the function bland.altman.stats from the BlandAltmanLeh package version 0.3.1. Data from Beaulieu et al. (2017).

CONCLUSION

This paper offers a simple set of recommendations (table 2) to implement or develop cultural or nutritional adaptations of the LFPQ. After many studies using the LFPQ, this protocol is intended to be adaptable and open to future improvements and investigations. Following this protocol will assure better quality and sensitivity in the measurements of food reward and will help to draw comparisons between studies. This guidance will contribute to standardised investigation of the distinct role of explicit liking and implicit wanting in different cultural and scientific contexts and improve our understanding of food preferences and reward in human appetite.

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AUTHOR CONTRIBUTIONS

P.O., D.T., M.D and G.F. contributed to the design of the protocol. P.O. and G.F. contributed to the data analysis; P.O., D.T., M.D., K.B., C.G., M.H., J.B. and G.F contributed to the writing of the manuscript. All authors read and approved the final version of the manuscript.

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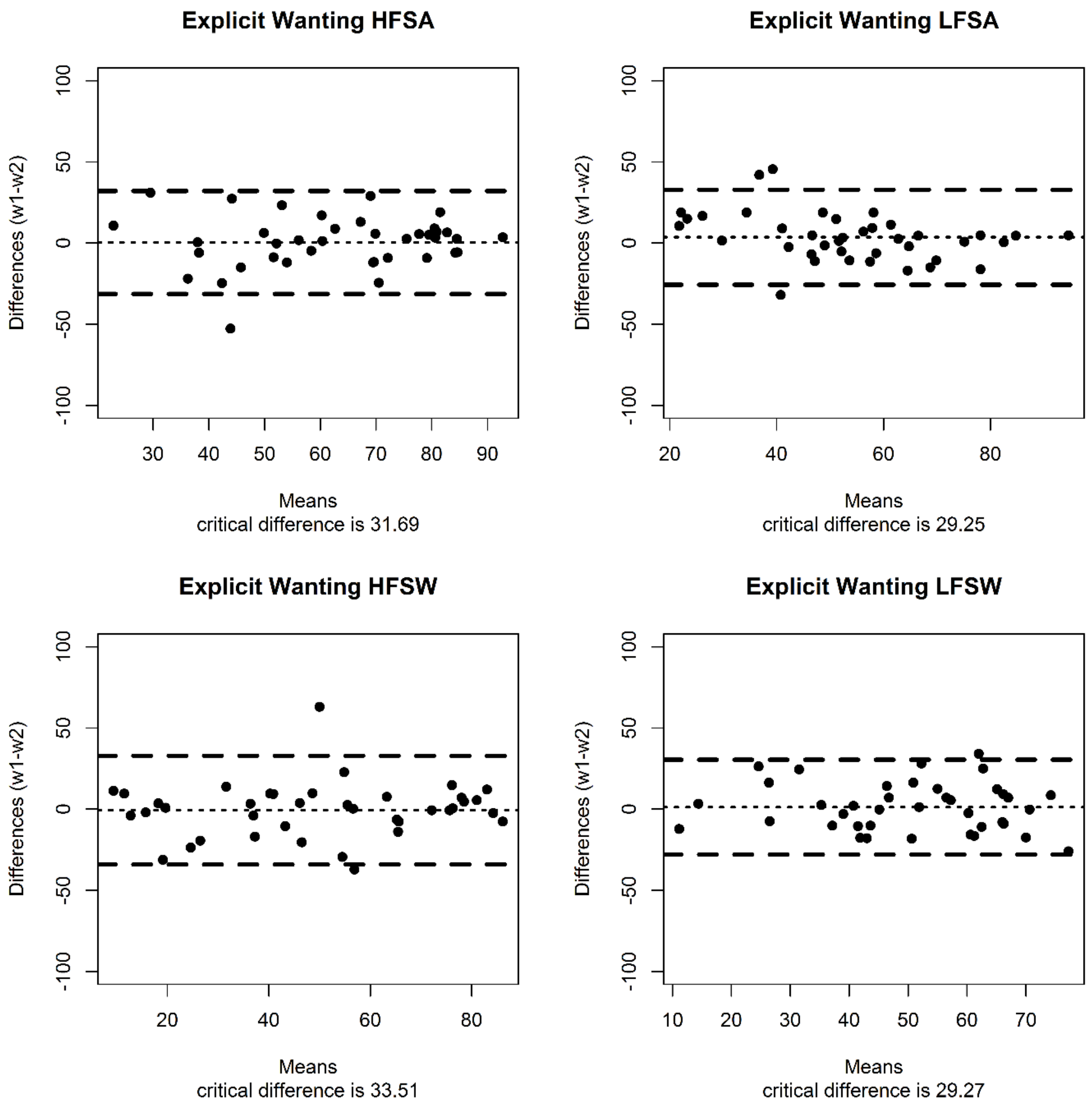
SUPPLEMENT

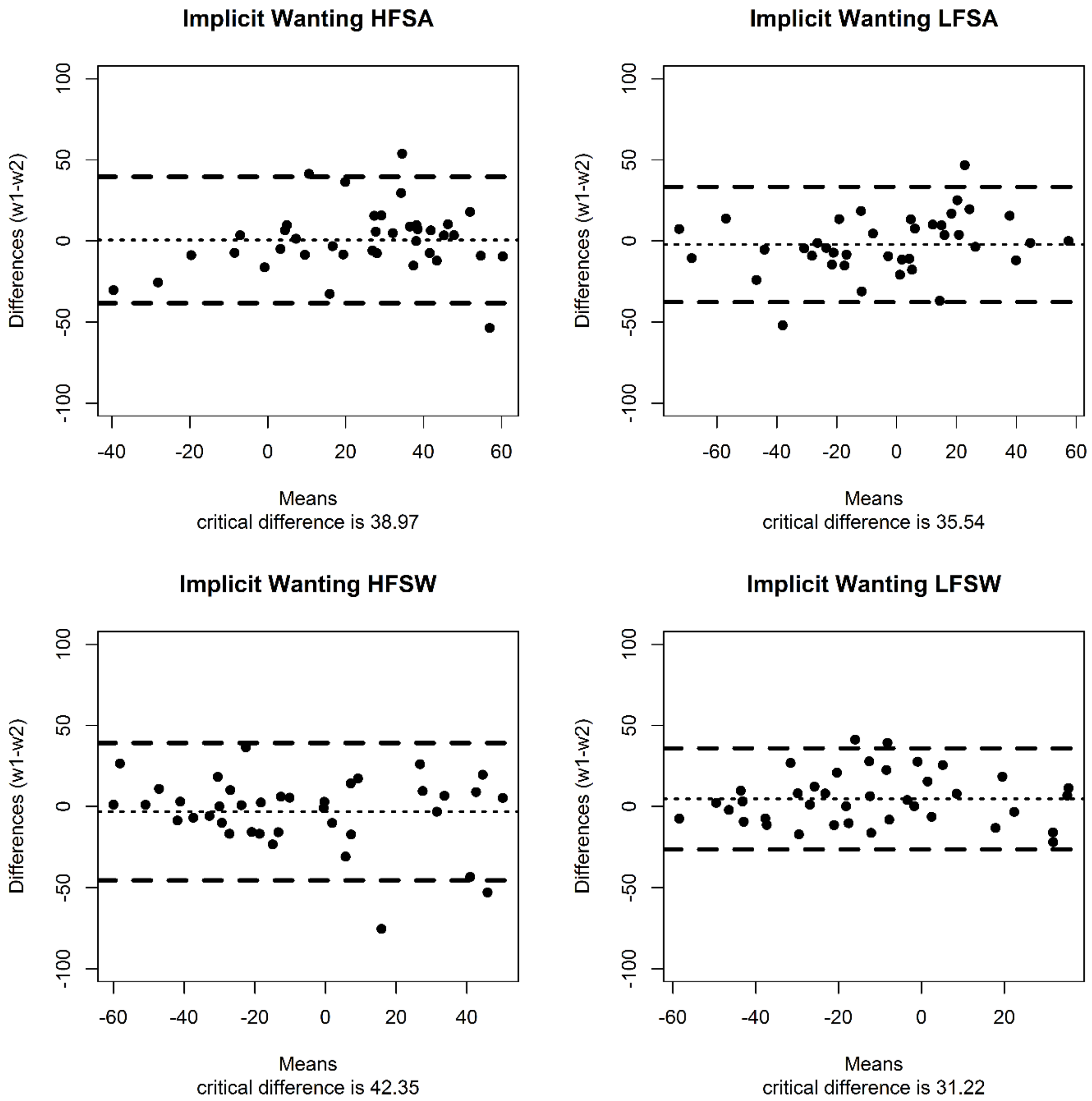
R codes for the hierarchical clustering and the cluster graph

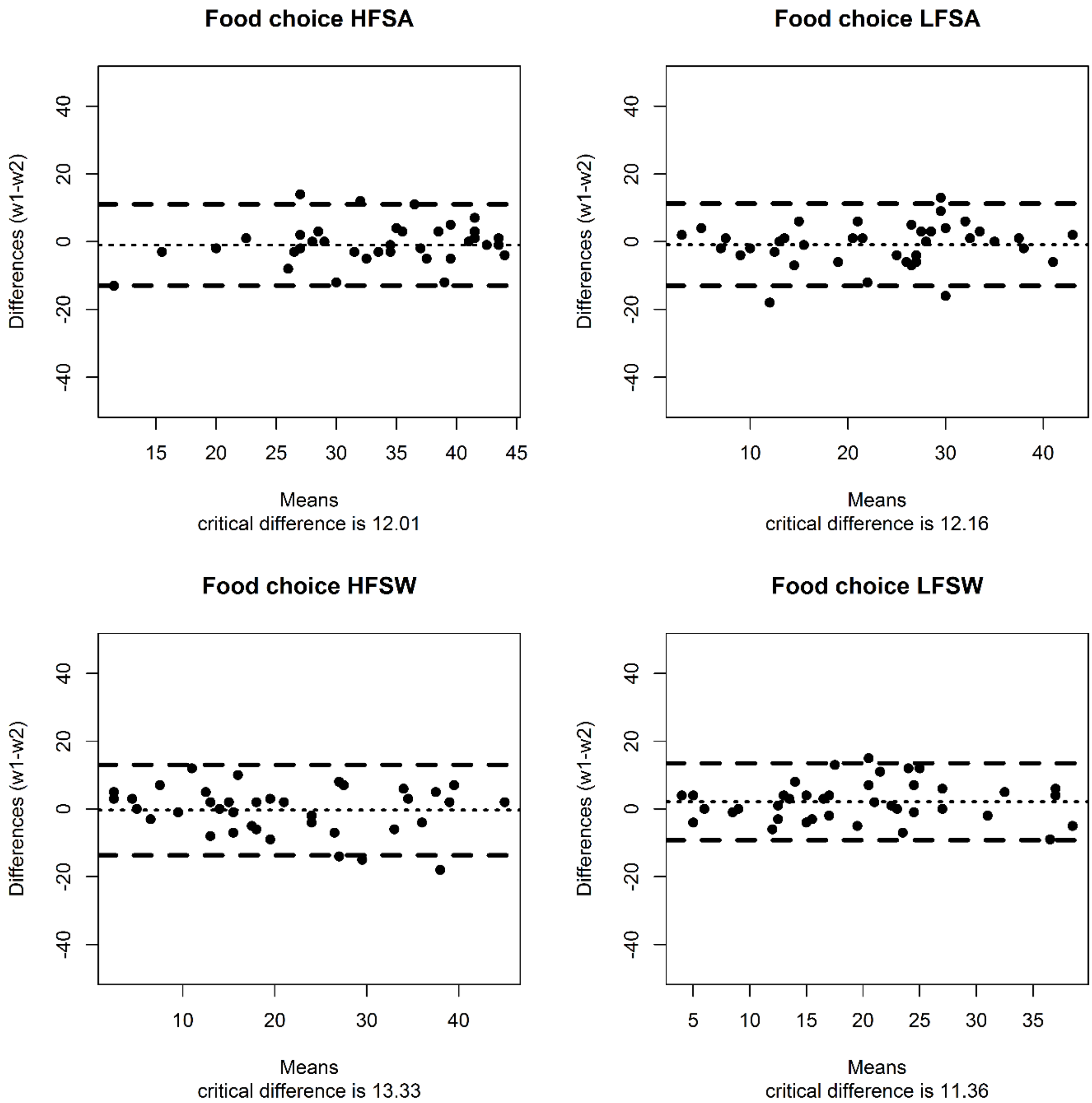
```
# Enhanced hierarchical clustering
res.hc <- eclust(df[,c("Taste","Fat")], "hclust", hc_metric = "euclidean",
            hc_method = "ward.D2", k=4)

#Rename the food by their labels
res.hc$labels <- df$Names
rownames(res.hc$data)<-res.hc$labels

#Create the scatter plot
p <- fviz_cluster(res.hc,
            repel = T,
            show.clust.cent = TRUE,
            ellipse.type = "confidence",
              label = 14,
            show.legend = FALSE,
            )
p <- p + PO_theme
p <- p + scale_fill_discrete(name = "cluster", labels = c("HFSA","HFSW",
"LFSA","LFSW"))
p

PO_theme <- theme_classic()+
  theme(axis.text  = element_text(color= "black", size= 14))+
  theme(axis.title = element_text(color= "black", size= 14))+
  theme(legend.text = element_text(color= "black", size= 14))+
  theme(text = element_text(color= "black", size= 14))

#Save in high resolution
```

```
ggsave("Scatter.tiff", units="in", width=8,
    height=7, dpi=800, compression = 'lzw')
```

Bland-Altman plots




Implicit Wanting HFSA
Differences (w1-w2)
Means
critical difference is 38.97
Implicit Wanting LFSA
Differences (w1-w2)
Means
critical difference is 35.54
Implicit Wanting HFSW
Differences (w1-w2)
Means
critical difference is 42.35
Implicit Wanting LFSW
Differences (w1-w2)
Means
critical difference is 31.22


Food choice HFSA
Differences (w1-w2)
Means
critical difference is 12.01
Food choice LFSA
Differences (w1-w2)
Means
critical difference is 12.16
Food choice HFSW
Differences (w1-w2)
Means
critical difference is 13.33
Food choice LFSW
Differences (w1-w2)
Means
critical difference is 11.36