

Article

# Fat and carbohydrate interact to potentiate food reward in healthy weight but not in overweight or obesity

## Supplementary Materials

**Table S1.** Descriptive statistics for subjective ratings and willingness to pay (WTP) for foods across the three macronutrient categories from participants with healthy weight (HW; n = 30).

Subjective Variable (Units or scale range)	Carbohydrate M ± SD, Range	Fat M ± SD, Range	Combo M ± SD, Range
Liking (-100 to +100%)	18.6 ± 31.4, -100 to +100	17.3 ± 32.0, -100 to +83.0	20.3 ± 36.1, -100 to +89.3
Familiarity (0-100%)	86.0 ± 22.3, 0-100	79.7 ± 26.3, 0-100	83.5 ± 22.2, 0-100
Frequency (days/month)	2.40 ± 3.42, 0-15.04	2.83 ± 3.84, 0-20	2.31 ± 3.33, 0-15.29
Expected satiety (0-100%)	42.3 ± 26.0, 0-100	59.1 ± 19.4, 0-100	47.1 ± 23.0, 0-100
Healthiness (0-100%)	36.7 ± 24.3, 0-100	46.5 ± 20.0, 0-100	35.9 ± 22.3, 0-94.1
Estimated energy content (kcal)	115 ± 50, 17-240	122 ± 45, 21-240	110 ± 46, 0-240
Estimated energy density (0-100%)	49.0 ± 24.5, 0-100	66.8 ± 17.2, 0-100	55.7 ± 22.4, 0-100
Estimated price (USD)	1.34 ± 0.96, 0.07-5	1.57 ± 1.11, 0-5	1.29 ± 0.99, 0.06-5
Willingness to pay (USD)	0.94 ± 0.96, 0-4.92	0.98 ± 1.09, 0-5	1.04 ± 0.95, 0-4.55

**Table S2.** Descriptive statistics for subjective ratings and WTP for foods across the three macronutrient categories from participants with overweight/obesity (OW/OB; n = 30).

Subjective Variable (Units or scale range)	Carbohydrate M ± SD, Range	Fat M ± SD, Range	Combo M ± SD, Range
Liking (-100 to +100%)	17.1 ± 32.4, -90.4 to +100	17.6 ± 31.0, -95.4 to +100	21.6 ± 30.4, -86.9 to +100
Familiarity (0-100%)	80.3 ± 24.0, 0-100	75.7 ± 28.0, 0-100	78.6 ± 24.6, 0-100
Frequency (days/month)	2.28 ± 3.57, 0-20	3.00 ± 4.12, 0-20	2.05 ± 2.82, 0-10.81
Expected satiety (0-100%)	43.5 ± 24.3, 0-100	55.8 ± 18.4, 0-100	43.5 ± 21.0, 0-94.9
Healthiness (0-100%)	37.4 ± 23.5, 0-94.6	48.3 ± 18.0, 0-100	35.9 ± 20.2, 0-81.4
Estimated energy content (kcal)	128 ± 52, 18-240	121 ± 48, 0-240	122 ± 53, 0-240
Estimated energy density (0-100%)	50.3 ± 22.0, 0-100	62.1 ± 14.6, 18.1-100	53.2 ± 30.9, 0-100
Estimated price (USD)	1.51 ± 0.99, 0.06-5	1.82 ± 1.10, 0.04-5	1.50 ± 0.97, 0.06-5
Willingness to pay (USD)	1.07 ± 0.98, 0-4.38	1.15 ± 1.07, 0-5	1.09 ± 0.98, 0-4.89

**Table S3.** Descriptive statistics and unpaired, two-sample t-tests on the Dietary Fat and Free Sugar Short Questionnaire (DFS) subscores and internal state ratings across BMI groups.

DFS Score or Internal State (Scale range)	HW M ± SD, Range	OW/OB M ± SD, Range	BMI Group Difference
DFS fat (0-55)	28.1 ± 5.7, 19-43	28.7 ± 6.0, 19-46	$t_{(1,58)} = 0.379$ , $p = 0.706$
DFS sugar (0-45)	18.7 ± 4.6, 11-29	18.2 ± 5.3, 9-32	$t_{(1,58)} = -0.346$ , $p = 0.731$
DFS fat-sugar (0-30)	13.6 ± 3.3, 7-20	12.7 ± 3.2, 9-22	$t_{(1,58)} = -1.143$ , $p = 0.258$
Hunger (0-100%)	71.5 ± 18.4, 0.1-97.4	67.1 ± 23.2, 0-99.4	$t_{(1,58)} = -0.819$ , $p = 0.416$
Fullness (0-100%)	23.9 ± 20.9, 0-84.7	23.2 ± 19.5, 0-66.0	$t_{(1,58)} = -0.122$ , $p = 0.903$
Thirst (0-100%)	69.4 ± 20.0, 25.4-100	73.2 ± 19.9, 20.0-100	$t_{(1,58)} = 0.751$ , $p = 0.456$
Desire to eat (0-100%)	72.1 ± 17.3, 26.7-98.9	66.4 ± 18.4, 25.9-100	$t_{(1,58)} = -1.241$ , $p = 0.220$

Potential to eat (0-100%)	71.4 ± 16.5, 26.5-100	66.4 ± 14.3, 26.5-98.0	$t_{(1,58)} = -1.257, p = 0.214$
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**Table S4.** BMI group interactions in the regressions between WTP, actual energy density (AED), and estimated energy density (EED), tested on averages per food across participants with HW versus OW/OB.

Variables	Foods Included	BMI Group Interaction
<b>Outcome: WTP</b>	All stimuli	$\beta = 0.104, p = 0.627$
<b>Predictors: AED × BMI Group</b>	Carbohydrate items	$\beta = -0.073, p = 0.858$
	Fat items	$\beta = 0.159, p = 0.690$
	Combo items	$\beta = 0.351, p = 0.262$
<b>Outcome: WTP</b>	All stimuli	$\beta = 0.017, p = 0.511$
<b>Predictors: EED × BMI Group</b>	Carbohydrate items	$\beta = 0.018, p = 0.736$
	Fat items	$\beta = 0.011, p = 0.885$
	Combo items	$\beta = 0.012, p = 0.838$
<b>Outcome: AED</b>	All stimuli	$\beta = -0.018, p = 0.480$
<b>Predictors: EED × BMI Group</b>	Carbohydrate items	$\beta = -0.006, p = 0.897$
	Fat items	$\beta = -0.028, p = 0.748$
	Combo items	$\beta = -0.061, p = 0.206$

**Table S5.** Correlations between actual energy density (AED) and characteristics and subjective ratings of foods in the combo category, tested on averages per food item across all participants.

Variable	Correlation with AED
Liking	$r^2 = 0.392, p = 0.029$
Familiarity	$r^2 = 0.002, p = 0.884$
Frequency	$r^2 = 0.327, p = 0.052$
Healthiness	$r^2 = 0.637, p = 0.002 *$
Expected satiety	$r^2 = 0.671, p = 0.001 *$
Estimated energy content	$r^2 = 0.229, p = 0.115$
Estimated energy density	$r^2 = 0.587, p = 0.004$
Estimated price	$r^2 = 0.835, p < 0.001 *$
Actual price	$r^2 = 0.859, p < 0.001 *$
Volume	$r^2 = 0.703, p < 0.001 *$
Visual area	$r^2 = 0.052, p = 0.478$
Fat content	$r^2 = 0.062, p = 0.436$
Carbohydrate content	$r^2 = 0.067, p = 0.417$
Protein content	$r^2 = 0.343, p = 0.046$
Sodium content	$r^2 = 0.550, p = 0.006$

\*  $p < 0.0033$  after Bonferroni correction for the 15 correlations performed

**Table S6.** Testing if the relationships of food volume and expected satiety with actual energy density differ across pairwise comparisons of foods in the three macronutrient categories.

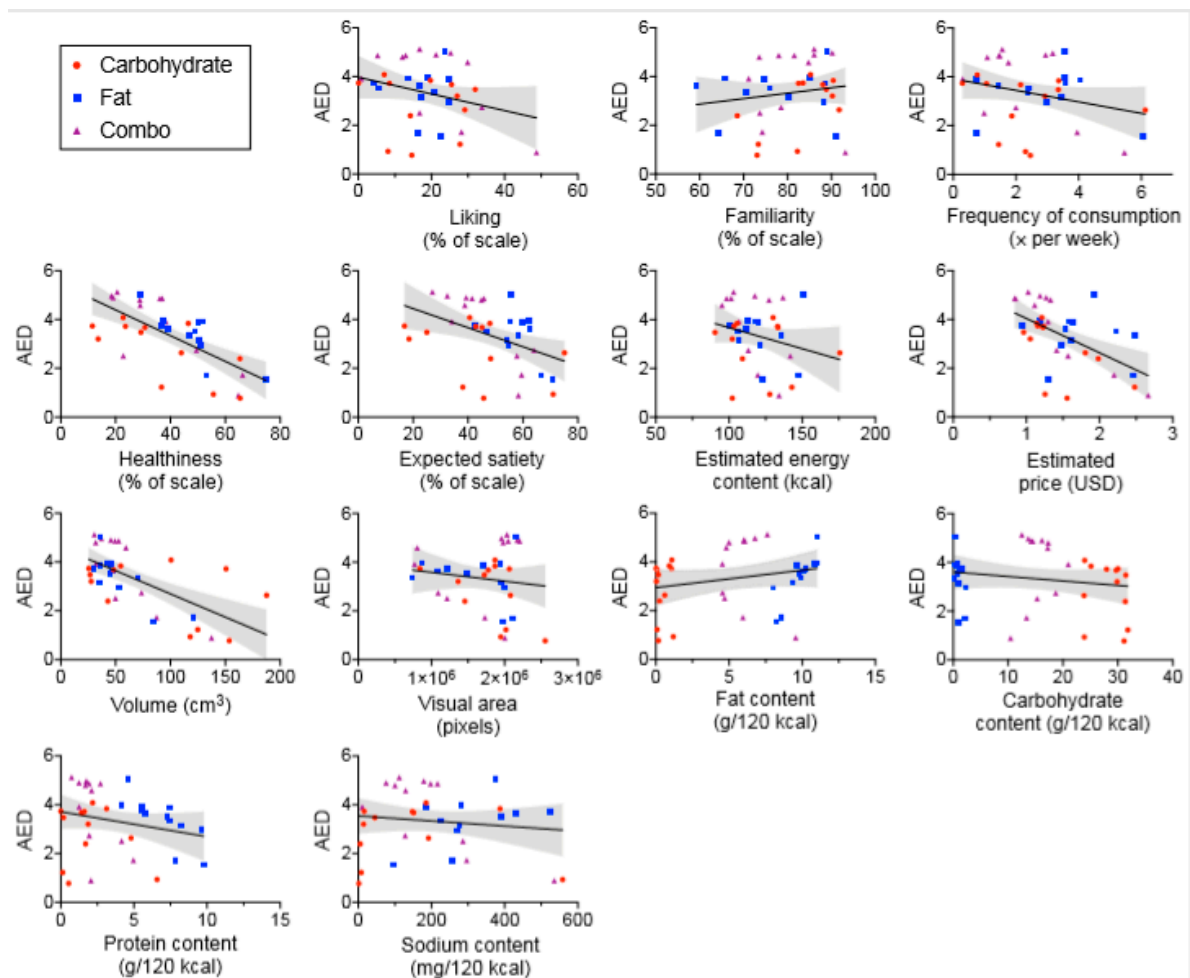
Variables	Pairwise Comparison	Macronutrient Category Difference
<b>Outcome: AED</b> <b>Predictors: Volume × Macronutrient</b>	Carbohydrate versus Fat	$t_{(1,20)} = 2.785, p = 0.011 *$
	Carbohydrate versus Combo	$t_{(1,20)} = 1.166, p = 0.257$
	Fat versus Combo	$t_{(1,20)} = 1.229, p = 0.233$
<b>Outcome: AED</b> <b>Predictors: Expected Satiety × Macronutrient</b>	Carbohydrate versus Fat	$t_{(1,20)} = 2.478, p = 0.022$
	Carbohydrate versus Combo	$t_{(1,20)} = 2.45, p = 0.024$
	Fat versus Combo	$t_{(1,20)} = 2.211, p = 0.039$

\*  $p < 0.017$  after Bonferroni correction for the 3 pairwise comparisons per combination of outcome and predictor variables.

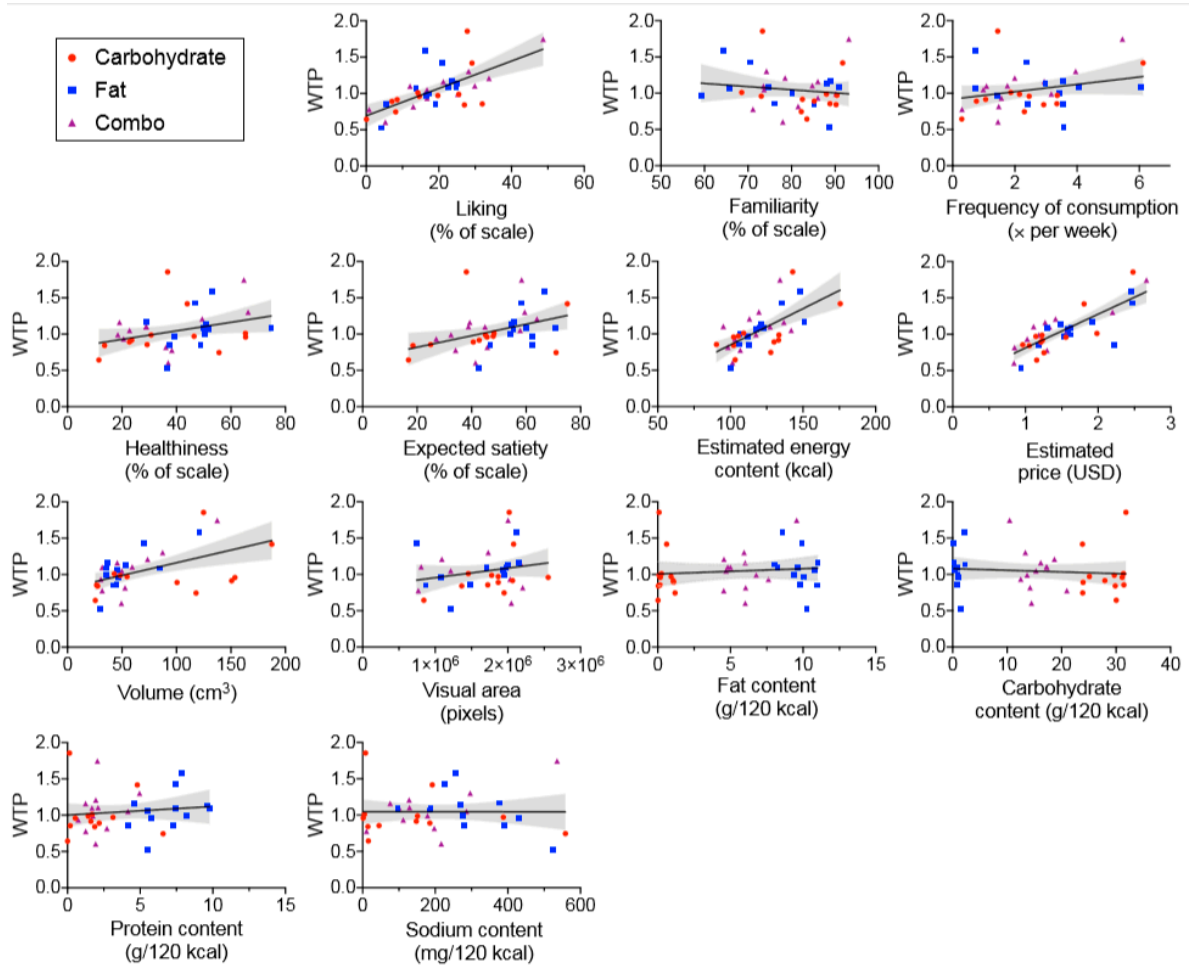
**Table S7.** Participant characteristics of the independent cohort for testing the modified picture set with varying food portions (N = 22).

Characteristic (Units)	Mean ± SD, Range
Sex	6 Male, 16 Female
Age (yr)	22.3 ± 6.6, 18-45
Education (yr)	14.5 ± 2.5, 12-20
Race	12 White, 1 Black/African American, 8 Asian, 1 More than one race
Ethnicity	2 Hispanic or Latino, 20 Not Hispanic or Latino
Household income <sup>1</sup>	5.2 ± 2.2, 1-8
Height (m)	1.68 ± 0.07, 1.58-1.79
Weight (kg)	62.35 ± 7.61, 48.10-77.25
Body mass index (kg/m <sup>2</sup> )	22.04 ± 1.72, 18.42-24.94
Waist-hip ratio	0.84 ± 0.07, 0.72-1.05
Body fat (%)	23.5 ± 7.1, 9.5-33.8

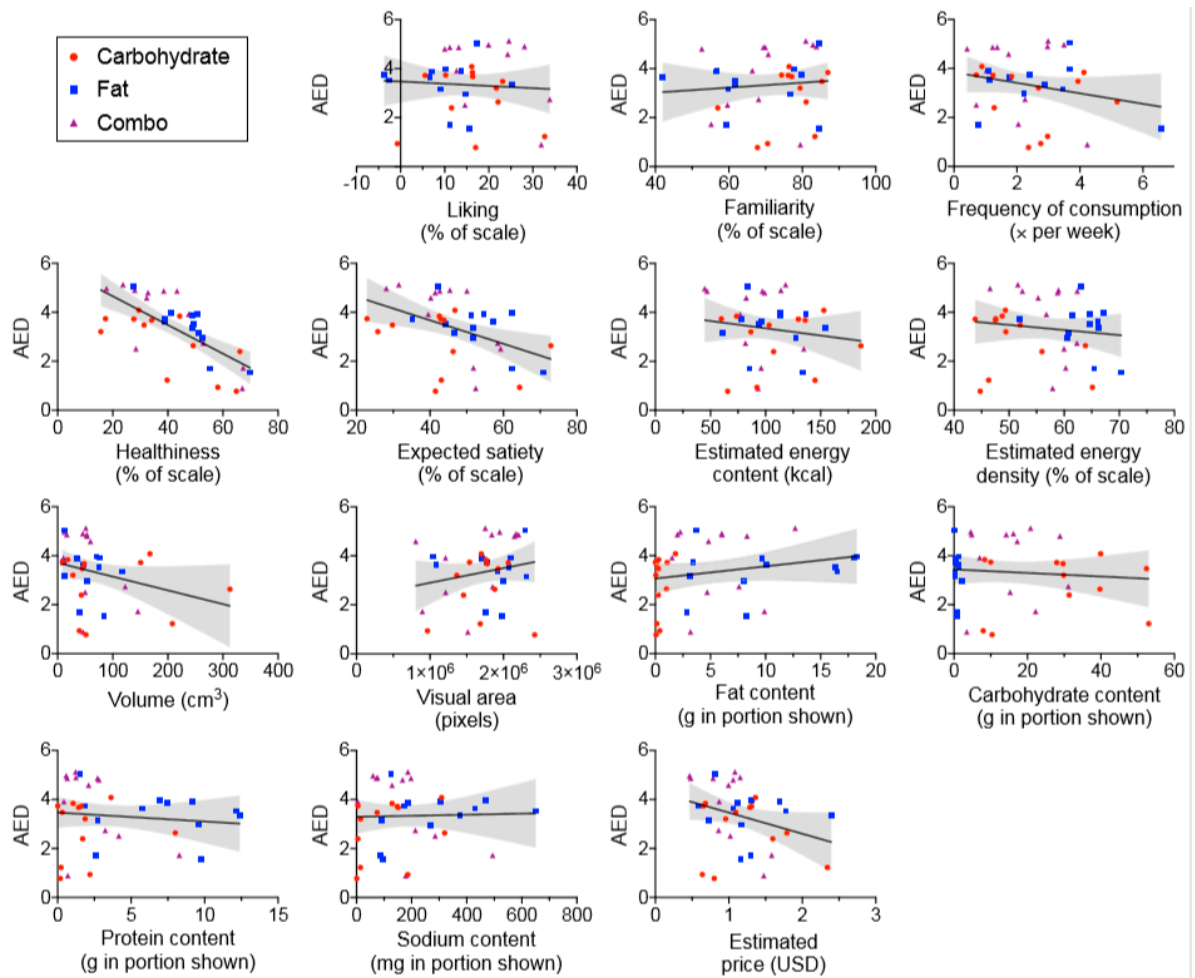
<sup>1</sup> Household income was dummy coded from 1-8 according to 2018 US Census Bureau income percentiles.



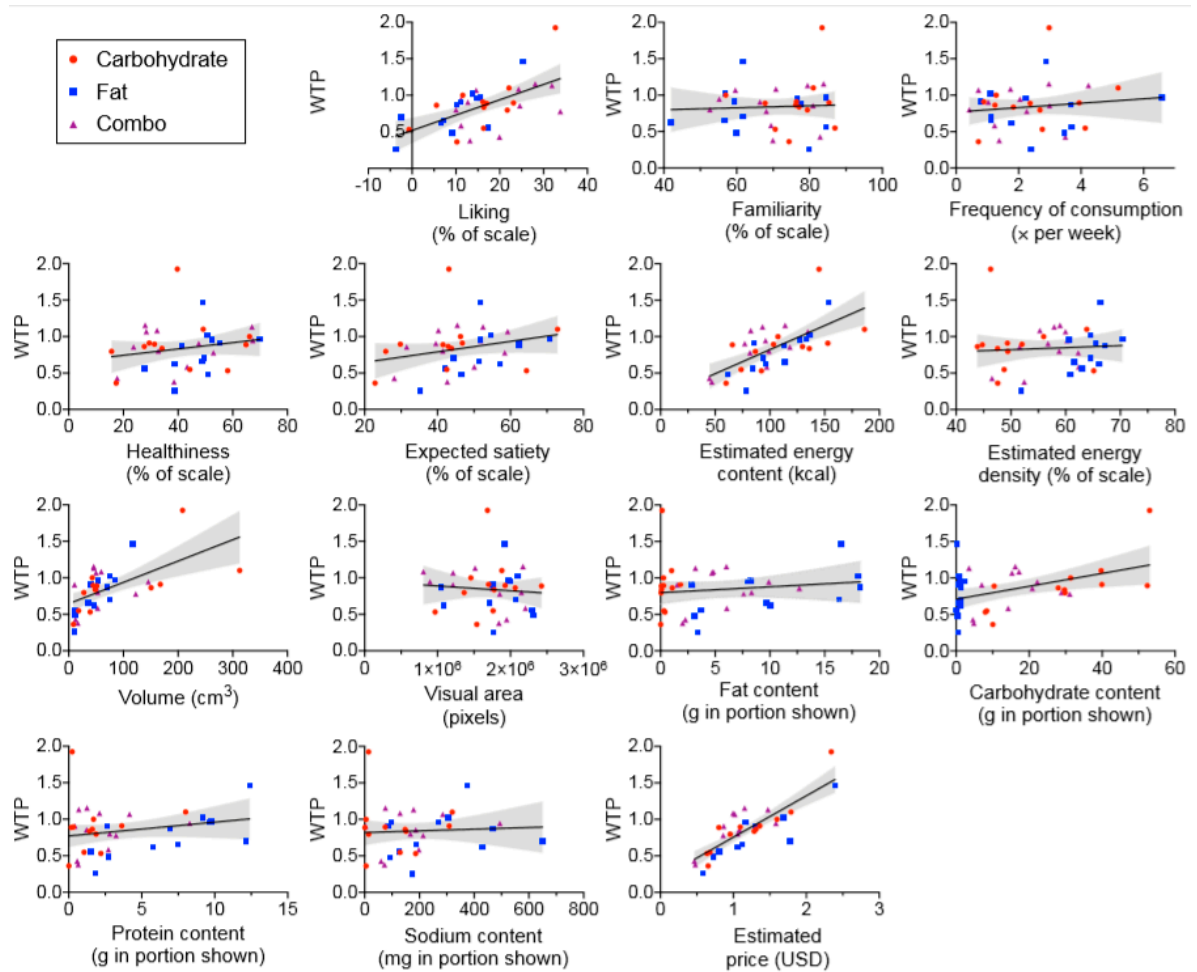
**Figure S1.** Fitted scatter plots comparing each food characteristic and subjective rating with actual energy density (AED, in g/120 kcal). Each data point represents a single food item from one of the three macronutrient categories (carbohydrate, fat, combo), with ratings averaged across all N = 60 participants (n = 30 HW and n = 30 OW/OB). Shading indicates 95% CI for the line of best fit.



**Figure S2.** Fitted scatter plots comparing each food characteristic and subjective rating with willingness to pay (WTP, in USD). Each data point represents a single food item from one of the three macronutrient categories (carbohydrate, fat, combo), with ratings averaged across all  $N = 60$  participants ( $n = 30$  HW and  $n = 30$  OW/OB). Shading indicates 95% CI for the line of best fit.



**Figure S3.** Fitted scatter plots comparing each characteristic and subjective rating with actual energy density (AED, in g/120 kcal) for foods pictured in varying portions (40, 120, 200 kcal). Each data point represents a single food item from one of the three macronutrient categories (carbohydrate, fat, combo), with ratings averaged across all N = 22 participants of the independent sample. Shading indicates 95% CI for the line of best fit.



**Figure S4.** Fitted scatter plots comparing each characteristic and subjective rating with willingness to pay (WTP, in USD) for foods pictured in varying portions (40, 120, 200 kcal). Each data point represents a single food item from one of the three macronutrient categories (carbohydrate, fat, combo), with ratings averaged across all N = 22 participants of the independent sample. Shading indicates 95% CI for the line of best fit.