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'How many calories are in my burrito?' Improving consumers' understanding of energy (calorie) range information

Peggy J Liu[1,*], James R Bettman[1], Arianna R Uhalde[2] and Peter A Ubel[1,3]
[1]Marketing Department, Fuqua School of Business, Duke University, 100 Fuqua Drive, Durham, NC 27708, USA:
[2]Marketing Department, Marshall School of Business, University of Southern California, Los Angeles, CA, USA:
[3]Sanford School of Public Policy, Duke University, Durham, NC, USA

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Abstract

Objective: Energy (calorie) ranges currently appear on menu boards for customized menu items and will likely appear throughout the USA when menu-labelling legislation is implemented. Consumer welfare advocates have questioned whether energy ranges enable accurate energy estimates. In four studies, we examined: (i) whether energy range information improves energy estimation accuracy; (ii) whether misestimates persist because consumers misinterpret the meaning of the energy range end points; and (iii) whether energy estimates can be made more accurate by providing explicit information about the contents of items at the end points.
Design: Four studies were conducted, all randomized experiments.
Setting: Study 1 took place outside a Chipotle restaurant. Studies 2 to 4 took place online.
Subjects: Participants in study 1 were customers exiting a Chipotle restaurant (*n* 306). Participants in studies 2 (*n* 205), 3 (*n* 290) and 4 (*n* 874) were from an online panel.
Results: Energy ranges reduced energy misestimation across different menu items (studies 1–4). One cause of remaining misestimation was misinterpretation of the low end point's meaning (study 2). Providing explicit information about the contents of menu items associated with energy range end points further reduced energy misestimation (study 3) across different menu items (study 4).
Conclusions: Energy range information improved energy estimation accuracy and defining the meaning of the end points further improved accuracy. We suggest that when restaurants present energy range information to consumers, they should explicitly define the meaning of the end points.

Keywords
Menu labelling
Nutrition information
Energy (calorie) ranges

Public health advocates and policy makers have pushed for restaurants to provide more information to consumers, allowing them to make more informed choices when placing orders. This objective is one rationale for a portion of the Patient Protection and Affordable Care Act, which mandates that all chain restaurants in the USA with twenty or more locations display energy (calorie) information on menus at the point of purchase[1].

Many menu-labelling proponents assume that menu labelling enables consumers to more accurately estimate the energy content of restaurant meals[2–4]. Indeed, a field study conducted outside fast-food restaurants in New York City, where menu-labelling legislation has already been implemented, found that menu labelling increased the percentage of consumers who could accurately estimate the energy in their meals (within 418 kJ (100 kcal)) from 15 % to 24 %[4]. However, most consumers continued to misestimate[4]. Although there are multiple reasons for this persistent misestimation, such as lack of awareness of point-of-purchase energy information[5], one important reason may be that many menu items (e.g. burritos, pizza) are customizable – with different people adding different ingredients – necessitating that energy information be presented as a range.

Energy ranges already appear widely in locations where menu-labelling legislation has been implemented[6]. One study found that most menu-board items in a New York City neighbourhood were presented with energy range rather than a single value[6]. Moreover, energy ranges will likely appear throughout the USA in coming years, as the Food and Drug Administration (FDA), tasked with determining menu-labelling regulations, has proposed that energy ranges should be used for customizable foods[7]. However, some health and consumer welfare groups (including the American Heart Association and the Center for Science in the Public Interest) have expressed concern

*Corresponding author: Email peggy.liu@duke.edu

about consumers' interpretation of energy ranges[8,9]. In addition, two US Congressional representatives recently criticized the FDA's proposed menu-labelling guidelines in an opinion piece, arguing that '[Energy] ranges can be so wide – conceivably as much as 2000 calories (8368 kJ) in the case of pizza – that they are useless in providing consumers with helpful information'[10].

Conventional wisdom suggests that energy range information should improve energy estimates, because the end points provide bounds for consumers' estimates. From there, individual consumers should estimate based on how many and which custom ingredients they added. However, misestimation might persist if consumers interpret the low end point to refer to the 'healthiest' version of the customized item – a version that includes all the healthiest ingredients – whereas many restaurants calculate the low end point to refer to a version of the customized item that includes the fewest number of ingredients.

Indeed, people frequently simplify nutrition information along a healthiness dimension and base energy estimates on healthiness perceptions[11,12]. This simplification leads to what experts call an 'averaging bias', the tendency to 'average' the healthiness of individual meal components to form an overall healthiness impression of the meal, which then affects the total energy estimate for the meal. Due to this averaging bias, a cheeseburger with lettuce and a tomato slice on top is judged to have less energy (fewer calories) than a cheeseburger by itself[13,14]. Building upon this finding, we argue that consumers interpret the low end point of the energy range to refer to the 'healthiest' version of the customized item – a version with all of the healthiest ingredients – rather than a version that includes the fewest ingredients.

In contrast, many restaurants calculate the low end point to refer to a version of the customized item that contains the fewest number of ingredients. For instance, at the popular chain restaurant Chipotle, the low end point of a burrito's energy range refers to a burrito composed solely of beans in a tortilla. By contrast, consumers might believe the low end point refers to multiple 'healthy' ingredients (e.g. chicken, beans, tomato salsa, lettuce) in a tortilla. Similarly, the pizza chain Domino's offers a medium pizza with a low end point that refers to pizza crust topped with only cheese and tomato sauce. Consumers might instead believe that the low end point refers to a pizza topped with cheese, tomato sauce and any toppings they think of as 'healthy'. It follows that when a consumer estimates the energy content of his own customized item based upon this incorrect belief, his estimate will be more inaccurate than it would be if he had accurate information about the contents of items at the end points.

In a series of studies, we tested: (i) whether energy range information improves the accuracy of energy estimates; (ii) whether misestimation persists in part because consumers misinterpret the meaning of the range end points; and (iii) whether energy estimates can be made more accurate by providing explicit information about the contents of items at the end points.

The present studies

Aspects of the methods and analyses that were common across all studies are presented first, before the individual studies.

Energy range calculation

As an example of how the energy range was constructed for each entrée, we briefly describe the calculation for one entrée examined: the burrito. Refer to online supplementary material (Table 1S) for more detailed information for the energy range calculation for the burrito and the other entrées examined.

The low end point for the burrito was calculated by adding the energy values for a tortilla (1213 kJ (290 kcal)) and black beans (502 kJ (120 kcal); www.chipotle.com). This definition of a burrito's minimum contents is inferred from a Chipotle menu board photographed in New York City in 2008. The high end point was calculated by adding the energy values for a tortilla (1213 kJ (290 kcal)), steak or chicken or carnitas (795 kJ (190 kcal)), chipotle-lime rice (544 kJ (130 kcal)), black or pinto beans (502 kJ (120 kcal)), corn salsa (335 kJ (80 kcal)), cheese (418 kJ (100 kcal)), sour cream (502 kJ (120 kcal)), guacamole (628 kJ (150 kcal)) and lettuce (21 kJ (5 kcal)).

Thus, participants assigned to see energy range information for a burrito saw a description of the burrito indicating that it had 1715 kJ (410 kcal) to 4958 kJ (1185 kcal). Note that when participants were shown energy range information, they actually only saw kilocalorie information, but this article reports both kilocalorie and kilojoule values.

Demographics

Participants in all studies reported gender, current age, height and weight. Self-reported height and weight were used to calculate BMI. Across studies, the average participant BMI fell in the overweight range, according to standard BMI cut-offs. See Table 1 for a summary of demographic characteristics across studies.

Measures

For all studies, the outcomes were energy estimates, absolute error and percentage misestimation.

Statistical analyses

For all studies, we first confirmed that actual energy content of the ordered entrée did not differ significantly across conditions for a given entrée. This similarity in actual energy content of the ordered entrée across conditions allowed us to compare energy estimates across conditions without needing to control for actual energy content.

Table 1 Demographic characteristics of the participants across studies

Study	No. of consumers	Gender (% female)	Age (years)		BMI (kg/m^2)	
			Mean	SD	Mean	SD
1	306	47·5*	31·97†	11·26†	25·73‡	5·49‡
2	205	49·8	30·42	11·36	26·34	6·36
2 (pre-test)	101	41·6	30·70	10·05	25·65	6·20
3	290	45·2	31·19	11·20	26·46	7·52
4	874	49·4	32·95	11·32	26·41	6·60

*n 299; missing gender data for seven participants.
†n 303; missing age data for three participants.
‡n 291; missing height and/or weight data for fifteen participants.

Because energy estimates were skewed, parametric tests were conducted on trimmed data[15]. Following recommended guidelines for trimming data[15], participants with the highest and lowest 5 % of energy estimates within a given condition were excluded.

Paired t tests comparing energy estimates and actual energy content were conducted to examine whether participants underestimated energy content, overestimated energy content or were accurate at estimating energy content for each condition. If the paired t test indicated that energy estimates were significantly lower (higher) than actual energy content, then we determined that underestimation (overestimation) occurred. If the paired t test was not significant, then we determined that consumers were accurate at estimating energy content.

ANOVA were conducted on energy estimates, absolute error and percentage misestimation, with follow-up comparisons conducted if an ANOVA was significant and there were more than two conditions. With one exception, percentage misestimation results confirmed absolute error results, so percentage misestimation ANOVA results are not presented. The one exception was for burrito bowls in study 1, for which results differed due to a marginally significant effect of condition on actual energy content ($P = 0{\cdot}057$).

Additional analyses were also conducted to examine the robustness of the results to alternative forms of analysis and to test whether controlling for participant demographic characteristics influenced the results. These additional analyses are not presented because they did not change any conclusions. First, ANCOVA with actual energy as a covariate produced the same conclusions as the ANOVA on the energy estimates outcome. Second, non-parametric analyses using non-trimmed data produced the same conclusions as the parametric analyses using trimmed data. Third, ANCOVA controlling for participant demographic characteristics (gender, age, BMI) produced the same conclusions as the ANOVA on the energy estimates outcome.

Finally, we ran additional analyses examining whether the results differed depending upon participants' weight status. We tested participants' weight status as a categorical moderator using a BMI cut-off value of 25 kg/m^2, separating participants into overweight/obese (BMI $\geq$25 kg/m^2) and non-overweight/non-obese (BMI $<$ 25 kg/m^2). With one exception (burrito bowls in study 1), the results did not differ depending upon participants' weight status. For burrito bowls, there was no effect of range information on estimation accuracy for overweight/obese participants, but range information increased estimation accuracy for non-overweight/non-obese participants. We repeated these analyses including participants' BMI as a continuous moderator and found the same results.

All tests were based on a 0·05 two-sided significance level. Data were analysed using the statistical software package IBM SPSS Statistics 20·0.

Study 1: Field study

Study 1 tested our hypothesis that providing energy range information would improve the accuracy of consumers' energy estimates for their customized food orders because the end points provide bounds for consumers' estimates. However, we hypothesized that some misestimation might persist despite the provision of energy range information.

Methods

Restaurant selection

We selected Chipotle because it is a popular chain restaurant (total revenue of $US 2·2 billion in 2011[16]) that provides nutrition information online and has a menu of four customizable entrées.

Procedure

Researchers observed 1391 adults exiting a Chipotle restaurant in Durham, North Carolina, USA in the year 2012. Using a methodology similar to a 'street-intercept' survey, in which researchers intercept potential participants in their natural environments to ask them to participate in research[17,18], researchers approached 923 (66·4 %) adults exiting the Chipotle restaurant. Adults were not approached for the following reasons: they were talking on a cell phone; they were holding a young child; they were exiting too quickly for a researcher to approach; or all researchers were already busy administering surveys. Of the approached adults, 326 (35·3 %) consented to

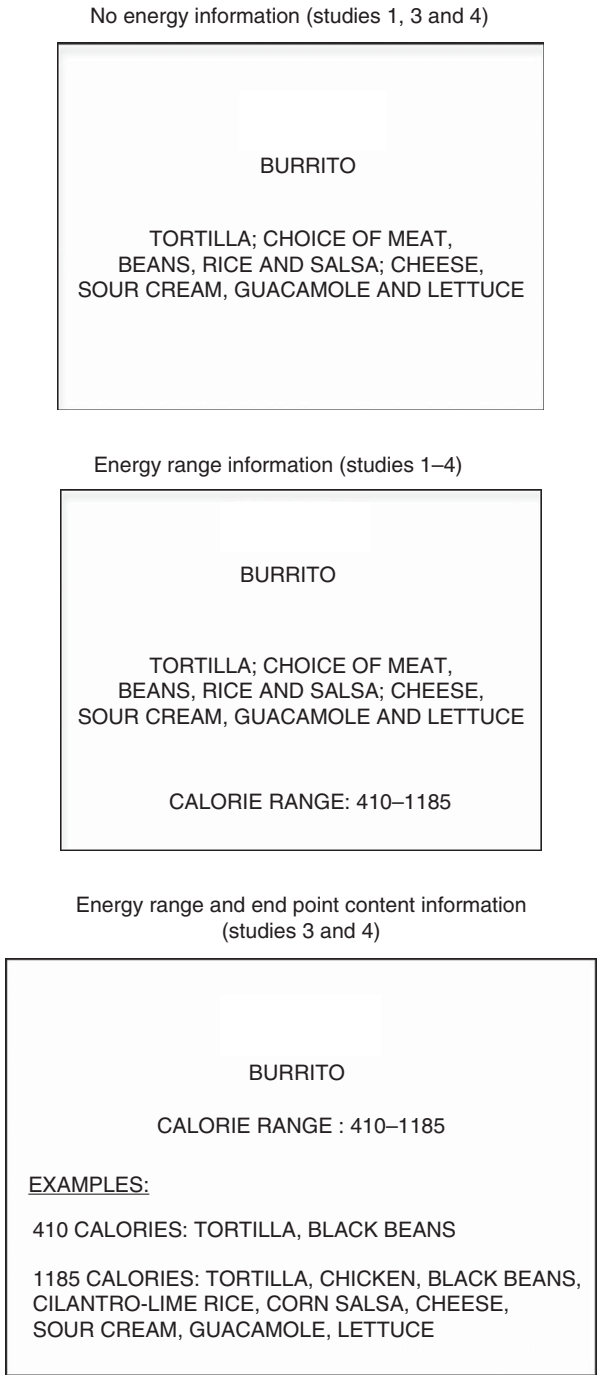

Fig. 1 Sample menus for burrito entrée

participate in a 5-min survey for compensation of a flavoured ice pop. We assessed survey participation rates by discreetly positioning one research assistant at each of the two exits of the restaurant to count the numbers of adult customers exiting the restaurant, approached to take a survey and agreeing to participate. Twenty respondents who consented to participate were excluded (fifteen because we were unable to determine energy estimates or energy ordered from their responses, two because they filled out a survey about another person's entrée and three because they inadvertently viewed a dining companion's survey while filling out their own survey), leaving a total of 306 respondents for our study.

Customers who agreed to participate filled out a survey specific to their selected entrée (burrito, burrito bowl, salad or tacos). The survey asked them to estimate the energy content (in calories) of their customized entrée. While estimating, participants were randomly assigned to see either: (i) no energy information; or (ii) energy range information. See Fig. 1 for sample menus across conditions. During the entire survey data collection period, our selected Chipotle restaurant did not display energy range information on its menu board.

After estimating, participants indicated how they had customized their entrée so that we could determine the energy content in their entrée. They did this by filling out an ingredient check-list to indicate what they added to their entrée. Finally, participants provided demographic information.

This study and the studies that follow were conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by Duke University Institutional Review Board. Participants in study 1 provided verbal informed consent by reading a consent form and telling an experimenter 'I agree to participate', and participants in studies 2 to 4 provided informed consent by reading an online consent form and clicking a button to indicate consent.

Results

Across conditions for all studies, Table 2 presents trimmed means for energy content estimates, actual energy content and absolute error. Figure 2 presents trimmed means for percentage misestimation.

The 306 valid responses consisted of 111 burritos, 158 burrito bowls, twenty-five salads and twelve tacos. Due to limited salad and taco orders, analyses were limited to burritos and burrito bowls. Thus, the total sample used for analysis consisted of 269 participants.

Burrito

Paired t tests indicated that participants significantly underestimated energy content both without ($t = 7{\cdot}18$; df = 44; $P < 0{\cdot}001$) and with energy range information ($t = 4{\cdot}73$; df = 55; $P < 0{\cdot}001$), but to a lesser degree with energy range information. An ANOVA revealed that estimates were significantly higher when energy range information was provided ($F = 9{\cdot}15$; df = 1,99; $P = 0{\cdot}003$). An ANOVA revealed a significant effect of energy range information on absolute error ($F = 17{\cdot}26$; df = 1,99; $P < 0{\cdot}001$), indicating that estimation was more accurate when energy range information was provided.

Burrito bowl

Paired t tests indicated that participants accurately estimated energy content both without ($t = 1{\cdot}04$; df = 67; $P = 0{\cdot}302$) and with energy range information ($t = -0{\cdot}65$, df = 73;

Table 2 Mean energy estimate, actual energy and absolute error across menu items and menu conditions

Study	Menu item	Menu condition	Trimmed no. of consumers	Energy estimate, mean		Actual energy, mean		Absolute error*, mean		Absolute error, ANOVA overall *P*
				kJ	kcal	kJ	kcal	kJ	kcal	
1	Burrito†	No energy information	45	2636	630	3849	920	1406	336	< 0·001
		Energy range information	56	3176	759	3703	885	803	192	
	Burrito bowl†	No energy information	68	2845	680	2987	714	895	214	0·042
		Energy range information	74	2820	674	2753	658	686	164	
2	Burrito	Range + no elaboration	91	3188	762	4000	956	937	224	0·905
		Range + elaboration	94	3075	735	3895	931	925	221	
3	Burrito†,‡,§	No energy information	92	2732	653	4050	968	1477	353	< 0·001
		Energy range information	84	3188	762	4021	961	908	217	
		Energy range and end point content information	84	3682	880	4054	969	669	160	
4	Pizza†,‡,§	No energy information	87	6159	1472	8289	1981	3766	900	< 0·001
		Energy range information	89	8054	1925	8301	1984	1536	367	
		Energy range and end point content information	89	8330	1991	8226	1966	996	238	
	Turkey sandwich†,‡	No energy information	84	2163	517	1858	444	519	124	< 0·001
		Energy range information	84	1854	443	1883	450	322	77	
		Energy range and end point content information	87	1958	468	1941	464	310	74	
	Chicken meal†,‡	No energy information	87	3803	909	3925	938	1188	284	< 0·001
		Energy range information	91	3690	882	3845	919	820	196	
		Energy range and end point content information	86	3879	927	3925	938	720	172	

*Absolute error was calculated by taking the absolute difference between actual energy content and energy content estimates.
†Significant difference between the No energy information and Energy range information conditions at the $P < 0·05$ level.
‡Significant difference between the No energy information and Energy range and end point content information conditions at the $P < 0·05$ level.
§Significant difference between the Energy range information and Energy range and end point content information conditions at the $P < 0·05$ level.

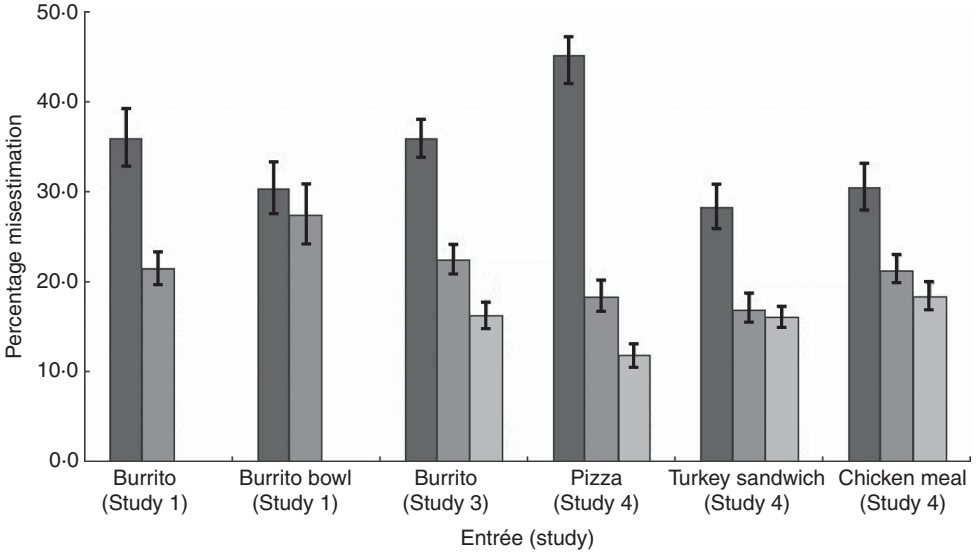

Fig. 2 Mean percentage misestimation of energy across menu items and menu conditions (■, no energy information; ■, energy range information; ■, energy range and end point content information). Percentage misestimation was calculated by dividing the absolute difference between actual energy content and energy content estimates by actual energy content and multiplying by 100 %. Values are trimmed means with their standard errors represented by vertical bars

$P = 0·518$). An ANOVA revealed no significant effect of energy range information on energy estimates ($F = 0·03$; df = 1,140; $P = 0·867$). An ANOVA revealed a significant effect of energy range information on absolute error ($F = 4·23$; df = 1,140; $P = 0·042$), but this significant effect was due to a marginally significant difference in actual energy, not estimated energy.

Discussion

Energy range information improved the accuracy of consumers' energy estimates when accuracy was not already attained in the absence of energy range information. However, consumers continued to misestimate energy content for one of the two entrées – the burrito – when range information was provided.

Study 2: Elaborating on end point content

Study 2 examined consumers' beliefs about the contents of customized burritos corresponding to the low and high end points of the energy range. We hypothesized that

consumers interpret the energy range in terms of healthiness, believing that the low end point refers to the 'healthiest' version of the customized item rather than a version with the fewest ingredients.

Study 2 also tested whether explicitly drawing participants' attention to the energy range end points increases estimation accuracy. If simple lack of attention to the end points is one reason why consumers sometimes misestimate energy content even when range information is provided, then participants asked to pay attention to the range end points before estimating energy content should have more accurate energy estimates. If it is not, then asking participants to pay attention to the range end points before estimating energy content should not make energy content estimates more accurate.

Methods

Procedure

Participants in studies 2 to 4 were recruited from Amazon Mechanical Turk, an online panel, to participate in exchange for monetary compensation. Amazon Mechanical Turk is an online labour market in which employers, such as researchers, post surveys and other tasks for people to complete if they meet certain criteria. This online panel is more demographically representative of the US population than traditional undergraduate participant pools[19,20]. Studies 2 to 4 were advertised as surveys about consumer choices, and the inclusion criteria were that participants had to be at least 18 years of age and had to be located in the USA, where kilocalories are the predominant units used to express energy information.

For study 2, participants (n 205) were recruited in the year 2012 and asked to imagine ordering a burrito at a casual chain-style Mexican restaurant. They then customized a burrito by indicating which ingredients they would order as fillings. Participants were then randomly assigned to either: (i) first, estimate the energy content of their customized burrito while viewing energy range information and second, indicate what they thought a 1715 kJ (410 kcal) burrito and a 4958 kJ (1185 kcal) burrito would contain; or (ii) to perform the same two tasks in the reverse order. Finally, participants provided demographic information.

Healthiness perceptions

To test our predictions that participants would interpret the energy range in terms of healthiness, we conducted a pre-test with a separate group of participants (n 101) recruited from Amazon Mechanical Turk in the year 2012. Pre-test participants rated the healthiness of each burrito ingredient on a scale from −50 (very unhealthy) to +50 (very healthy). Having a separate group of participants rate the healthiness of each ingredient ensured that the main study's experimental manipulation could not affect healthiness perceptions and is consistent with methods used in other studies[21,22].

Results

End point beliefs

Study 2's first aim was to directly test consumers' interpretation of the meaning of the energy range end points. Table 2S in the online supplementary material shows the percentage of participants who included each ingredient in the burritos they constructed to be 1715 kJ (410 kcal) and 4958 kJ (1185 kcal). Table 2S also shows how pre-test participants perceived the healthiness of each ingredient.

As predicted, although a 1715 kJ (410 kcal) burrito actually contains just beans, most participants (63·5 %) thought it contained four or five ingredient categories. Moreover, as the pre-test results in Table 2S show, these were generally ingredients perceived to be healthy. In addition, most participants (78·5 %) thought a 4958 kJ (1185 kcal) burrito would be fully loaded with all ingredient categories. As the pre-test results in Table 2S show, these were generally ingredients perceived to be unhealthy. These findings support our prediction that consumers interpret the low end point to be the 'healthiest' burrito and the high end point to be the 'unhealthiest' loaded burrito. An examination of the energy content of burritos that participants constructed to correspond to the end points further supports the notion that consumers are especially inaccurate when interpreting the low end point. Burritos perceived to be at the low 1715 kJ (410 kcal) end point in reality contained an average of 2707 kJ (647 kcal), significantly higher than 1715 kJ (410 kcal; $t = 16{\cdot}29$; df = 180; $P < 0{\cdot}001$). In contrast, burritos perceived to be at the high 4958 kJ (1185 kcal) end point contained an average of 5071 kJ (1212 kcal), which was significantly greater than 4958 kJ (1185 kcal; $t = 3{\cdot}18$; df = 180; $P = 0{\cdot}002$), but much more accurate than beliefs about the low end point.

Alternative explanation

Study 2's second aim was to test whether drawing participants' attention to the energy range end points might increase estimation accuracy. The data from study 2 suggest that merely increasing participants' attention to the energy range end points does not improve estimation accuracy: energy content estimates and absolute error did not differ depending upon whether participants elaborated on end points before or after estimating energy in their customized entrée ($P = 0{\cdot}259$; $P = 0{\cdot}905$).

Discussion

Study 2 demonstrated that increasing attention to the energy range end points did not improve energy estimates, indicating that persistence of misestimation is not due to lack of attention to the end points. In addition, study 2 demonstrated that consumers appear to interpret the low end point of the energy range to refer to the 'healthiest' version of the customized item rather than a version that includes the fewest ingredients to still qualify as an item in that category. Study 2 therefore suggests that

providing explicit information about end point contents may improve energy estimation accuracy, a prediction that we test in studies 3 and 4.

Study 3: Debiasing by providing correct end point content information

Study 3 tested our hypothesis that providing explicit information about energy range end point content would improve energy estimation accuracy. This experiment is important because defining the contents of energy range end points can be used as an intervention for improving estimation accuracy that could also be realistically implemented without requiring much additional menu space.

Methods

Procedure

Participants (n 290) were recruited in the year 2012 and asked to imagine eating lunch at a casual chain-style Mexican restaurant and to indicate how they would customize their burrito. Participants did not see energy range information while ordering. Participants then estimated how much energy content was in their customized burrito. While estimating, participants were randomly assigned to see: (i) no energy information; (ii) energy range information; or (iii) energy range and end point content information. See Fig. 1 for the format of the information. Finally, participants provided demographic information.

Results

Burrito

Paired t tests indicated that participants significantly underestimated energy content when no energy information was provided ($t = 11{\cdot}29$; df = 91; $P < 0{\cdot}001$), when energy range information was provided ($t = 10{\cdot}16$; df = 83; $P < 0{\cdot}001$) and when energy range and end point content information was provided ($t = 4{\cdot}17$; df = 83; $P < 0{\cdot}001$), but to a progressively smaller degree in each case. Indeed, an ANOVA on energy estimates was significant ($F = 24{\cdot}93$; df = 2,257; $P < 0{\cdot}001$); estimates were higher when range information was provided *v.* not provided ($P = 0{\cdot}001$) and higher when end point information was provided *v.* not provided alongside the range ($P < 0{\cdot}001$). An ANOVA on absolute error was also significant ($F = 28{\cdot}36$; df = 2,257; $P < 0{\cdot}001$), such that accuracy was greater when energy range information was provided *v.* not provided and when end point information was provided *v.* not provided alongside the energy range.

Discussion

These results replicated study 1's findings that energy range information alone increases estimation accuracy. Importantly, these results also demonstrated that providing end point content information might further improve estimation accuracy.

Study 4: Generalizability experiment

Study 3 showed that providing end point content information further improves estimation accuracy for one entrée: the burrito. If such an intervention were to be implemented widely, it would be important to establish that providing such additional information consistently helps and does not hurt the accuracy of energy estimates. Therefore, study 4 tested our hypothesis that providing explicit information about energy range and end point content would consistently improve and would not hurt people's energy estimates by testing this intervention with three new customizable menu items: pizza, a turkey sandwich and a chicken meal.

Methods

Procedure

Participants (n 874) were recruited in the year 2013 and were asked to imagine eating lunch at a fast-food restaurant and to indicate how they would customize their randomly assigned entrée – a pizza, a turkey sandwich or a chicken meal. Participants did not see energy range information while they customized their entrée. Participants then estimated the energy content in their customized entrée. While estimating, participants were randomly assigned to be given: (i) no energy information; (ii) energy range information; or (iii) energy range and end point content information. Thus, participants were randomly assigned to one of nine conditions (three entrée types by three information conditions). Finally, participants provided demographic information.

The purpose of using a completely between-subjects design rather than having each participant customize three separate entrées was to mitigate participant fatigue and potential asymmetric carryover effects, which cannot be eliminated through a counter-balanced design. Although between-subjects designs have less statistical power than within-subjects designs, study 4 has approximately 100 participants per condition, consistent with the sample sizes of studies 2 and 3.

Results

Pizza

Paired t tests indicated that participants significantly underestimated energy content when no energy information was provided ($t = 5{\cdot}01$; df = 86; $P < 0{\cdot}001$) but not when energy range information was provided ($t = 1{\cdot}10$; df = 88; $P = 0{\cdot}273$) or when energy range and end point content information was provided ($t = -0{\cdot}66$; df = 88; $P = 0{\cdot}511$). Indeed, an ANOVA on energy estimates was significant ($F = 16{\cdot}55$; df = 2,262; $P < 0{\cdot}001$), such that estimates were higher when range information was provided *v.* not provided ($P < 0{\cdot}001$); estimates were not significantly different when end point information was provided *v.* not provided alongside the range ($P = 0{\cdot}50$).

An ANOVA on absolute error was also significant ($F = 61{\cdot}17$; df = 2,262; $P < 0{\cdot}001$), revealing that accuracy was greater when energy range information was provided *v.* not provided and when end point information was provided *v.* not provided alongside the range.

Turkey sandwich

Paired *t* tests indicated that participants significantly overestimated energy when no energy range information was provided ($t = -4{\cdot}75$; df = 83; $P < 0{\cdot}001$) but not when energy range information was provided ($t = 0{\cdot}58$; df = 83; $P = 0{\cdot}561$) or when energy range and end point content information was provided ($t = -0{\cdot}43$; df = 86; $P = 0{\cdot}670$). Indeed, an ANOVA on energy estimates was significant ($F = 8{\cdot}91$; df = 2,252; $P < 0{\cdot}001$), such that estimates were higher when range information was provided *v.* not provided ($P = 0{\cdot}001$); estimates were not significantly different when end point information was provided *v.* not provided alongside the range ($P = 0{\cdot}159$). An ANOVA on absolute error was also significant ($F = 10{\cdot}84$; df = 2,252; $P < 0{\cdot}001$); energy estimates were more accurate when energy range information was provided *v.* not provided but similarly accurate when end point information was provided *v.* not provided alongside the energy range.

Chicken meal

Paired *t* tests indicated that participants did not significantly over- or underestimate energy when no energy range information was provided ($t = 0{\cdot}76$; df = 86; $P = 0{\cdot}449$), when energy range information was provided ($t = 1{\cdot}48$; df = 90; $P = 0{\cdot}143$) and when energy range and end point content information was provided ($t = 0{\cdot}48$; df = 85; $P = 0{\cdot}685$). Indeed, an ANOVA on energy estimates was not significant ($F = 0{\cdot}68$; df = 2,261; $P = 0{\cdot}51$). An ANOVA on absolute error was significant ($F = 10{\cdot}89$; df = 2,261; $P < 0{\cdot}001$); energy estimates were more accurate when energy range information was provided *v.* not provided and were similarly accurate when end point information was provided *v.* not provided alongside the energy range.

Discussion

Across the three entrées, study 4 replicated the findings of study 1 and study 3 that energy range information alone often increases estimation accuracy. Importantly, the results for the pizza entrée also demonstrated that providing end point content information can further improve estimation accuracy, and the results for the turkey sandwich and chicken meal demonstrated that providing end point content information does not hurt estimation accuracy.

The menu items in studies 3 and 4 varied along multiple dimensions, such that we can only speculate about why end point content information improves estimation accuracy for some items (burrito, pizza) while not affecting estimation accuracy for other items (turkey sandwich, chicken meal). One possibility is that the restaurant-determined end point definitions for the burrito and the pizza were the same – the low end point referred to a base item with no added ingredients and the high end point referred to a base item plus all possible ingredients. This range, once defined, may have allowed participants to situate their own customized items relatively easily by determining how many and which additional ingredients they added from all possible ingredients. In contrast, the restaurant-determined end point definitions for the turkey sandwich and chicken meal were different. For the turkey sandwich, the low end point referred to a turkey sandwich with multiple healthy ingredients added (see Table 1S) and the high end point referred to a turkey sandwich that did not contain all twelve sauces and spreads available. For the chicken meal, regardless of how it was customized, both the low end point and the high end point referred to a meal with two pieces of chicken, one biscuit and two side dishes; thus, consumers would already be aware of the number of 'ingredients' when estimating energy content in the absence of defined end points. Therefore, defining the range end points may have been less useful for the turkey sandwich and the chicken meal because the restaurant chain's definition of the low end point version of the turkey sandwich was already consistent with consumers' interpretation of it as the 'healthiest' turkey sandwich and because consumers could not misinterpret the number of 'ingredients' in the low end point version of the chicken meal.

Importantly, from a policy perspective, defining the range end points does not hurt the accuracy of energy estimates, while improving their accuracy for some menu items.

General discussion

Motivated by the notion that consumers should have accurate point-of-purchase energy information to make informed decisions, energy range information is being increasingly touted as a way to provide energy information for customizable foods[6,7]. However, both policy makers and consumer welfare groups have raised concerns about consumers' understanding of energy range information[8–10]. The present research produced three main findings: (i) energy range information improves energy estimation accuracy but some energy misestimation persists; (ii) an important cause of this misestimation is misinterpretation of the meaning of the low end point of the energy range; and (iii) defining the contents of the energy range end points further improves energy estimates. Thus, this research makes an important contribution to prior literature on energy estimation[2,4] by identifying energy ranges and consumers' misinterpretation of their meaning as one reason why consumers misestimate energy content even when energy information is provided.

One limitation of this research is that when seeking out energy range information for the entrées examined in the

study, the authors searched on the Internet for images of menu boards containing energy range information. Therefore, because these images of menu boards were taken in different years, a limitation is that the energy range information came from different years, spanning 2008 to 2012. If energy range information has changed over time, then the generalizability of these findings to different time periods is potentially limited. A second limitation of this research is that we did not measure participants' prior experience with the foods used in these studies. Therefore, future research might examine whether participants' prior experience with foods affects their ability to make use of energy range information.

We focused on examining the impact of energy range information on energy estimation accuracy rather than on food choices for several reasons. First, one objective of menu-labelling legislation is to promote more informed choices; thus, it is important to establish whether consumers understand such information. Second, the ability to understand and use energy information is one of several important prerequisites for menu labelling to impact food choices[5]. Although the ability to accurately estimate energy content from energy ranges may not affect food intake for all consumers, it may affect food intake for those consumers who are both motivated to use this information and find that the energy values differ from their expectations[5]. Finally, many complex factors potentially moderate the effect of energy range information on food choices, including consumers' motivations and ordering habits[5].

These findings have important public policy implications as menu-labelling implementation guidelines are currently being determined for US restaurants[6]. Researchers have called for point-of-purchase energy information to minimize persistent energy estimation biases[14,23,24]; our findings suggest that energy information format impacts the degree to which energy information minimizes estimation biases. Specifically, defining the energy range end points makes consumers more accurate or just as accurate compared with energy range information alone. Thus, when restaurants present energy range information to consumers, they should consider explicitly defining the meaning of the end points. In sum, our research contributes to and underscores the importance of consumer comprehension of different labelling formats[25–31].

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Supplementary material

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