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Estimating Food Quantity:
Biases and Remedies

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By

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When thinking about food, consumers focus on qualitative decisions about what to eat rather than quantitative decisions about how much to eat (Rozin et al. 1996). For example, a majority of Americans say that they clean their plates, no matter how much food they find there; even more think that to lose weight, the kind of food that they eat matters more than how much they eat (Collins 2006). Thinking of foods as either good or bad regardless of quantity is also common in the dieting industry and among policy makers who tend to promote qualitative remedies of the "eat this, not that" sort. For example, the USDA Dietary Guidelines for Americans (Thompson & Veneman 2005) contain dozens of recommendations on which food groups to encourage and which ones to avoid, but no guidance on how to better estimate portion or meal sizes.

The prevailing focus on consumer's qualitative decisions about food has obscured the importance of their quantitative judgments regarding how much food they should buy, store and consume. Understanding how people estimate food quantity—especially changes in food quantity—is particularly important given the current twin trends of supersizing and bulk buying, two of the primary drivers of the obesity epidemic (Ledikwe et al. 2005). Yet we have no overarching understanding of how people estimate food quantity, nor of the potential sources of bias in these estimations, nor of the interventions that can improve the accuracy of food quantity estimations.

In this chapter, I develop a framework of how people estimate food quantity, and particularly changes in food quantity. Following Arkes (1991), the framework distinguishes between quantity-based, salience-based and association-based biases, and allows us to make predictions about the effectiveness of three common remedies: education and motivation, increased salience, and piecemeal estimation. I then review empirical and experimental research which tests the predictions of the framework.

A FRAMEWORK OF HOW PEOPLE ESTIMATE FOOD QUANTITY

In out-of-home consumption contexts, quantity information is either not available or hard to obtain, so people have no choice but to estimate food quantity visually. For packaged food, people can obtain information about quantity from the label. However, surveys of shoppers have shown that many people do not read labels and rely instead on memory or on visual estimates. In some cases, this is because they think that the size of the package itself is a valid

proxy for the quantity of food it contains (Lennard et al. 2001). In others, it is because

quantity information is difficult to process, especially with non-metric units (Viswanathan et

al. 2005). Computing quantity information is even more difficult when people have to

aggregate across different unit sizes, for example, when estimating the quantity of food in a

home pantry or refrigerator. For all these reasons, food quantity is more often estimated

visually than computed and food quantity estimations are influenced by three potential

sources of bias: a) the quantity of the food itself, b) its visual salience, and c) its association

with health primes and numeric anchors.

Quantity-based Bias

Research in psychophysics (Stevens 1986) and in marketing (Krider et al. 2001) has shown

that quantity estimates follow an inelastic power function of actual quantity. This relationship,

known as the power law of sensation, can be expressed mathematically as:

(1) $$\text{ESTQ} = a \times (\text{ACTQ})^b,$$

where ESTQ is the estimated quantity, ACTQ is the actual quantity, a is an intercept, and b is

the power exponent which captures the elasticity of the estimation.

In her review of psychophysics research on quantity perception, Krishna (2007) showed that

power exponents b tend to fall between 0.5 and 1.0 and thus that estimations are inelastic to

the actual change in quantity. This inelasticity means that people underestimate the magnitude

of quantity changes. If the actual quantity is multiplied by a factor of r, the perceived quantity

is multiplied by a factor of $(r)^b$, which is a smaller number since b < 1. It also means that

quantity estimations are nonlinear and exhibit marginally decreasing sensitivity. In other

words, the subjective impact of increasing food quantity diminishes as the quantity of food

increases. As a result, underestimation becomes more likely and increases in magnitude as

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food quantity increases, even when the magnitude of the underestimation is measured as the percentage deviation from actual quantity (for mathematical proof, see Chandon & Wansink 2007b). Equation (1) implies that small quantities (below $ACTQ^* = a^{1/(1-b)}$) are likely to be overestimated, whereas large quantities (above $ACTQ^*$) are likely to be underestimated.

Salience-based Bias

Studies have shown that the power exponent measuring the elasticity of estimations is influenced by the perceptual salience of the different spatial dimensions of the stimulus. For example, Krider, Raghubir and Krishna (2001) found that the power exponent of area estimations for two-dimensional objects is greater when the salience of secondary dimensions (those which are not used as anchors) is increased. Building on this idea, I predict that visual salience will also be influenced by the number of spatial dimensions that change when food quantity changes. Food marketers can supersize a package by increasing only one dimension, (e.g., its height) or by increasing all three spatial dimensions (height, width and length). This hypothesis is supported by prior research which showed that three-dimensional objects (e.g., spheres) appear to grow more slowly than one-dimensional objects (e.g., segments), partly because it is visually easier to notice quantity changes when only one dimension changes. (For a review, see Krishna 2007).

Generalizing these findings, I also predict that the elasticity of quantity estimation will increase with the perceptual salience of the food quantity itself (e.g., its visibility at the time of the estimation). For example, estimation should be more sensitive to a change in quantity when food quantity is highly visible than when it is not.

Association-based Bias

When estimating food quantity, associations with numeric reference points or semantic primes can bias estimations through a variety of mechanisms such as selective accessibility, anchoring and adjustment, or conversational norms (Krishna & Raghubir 1997; Mussweiler 2003; Wansink et al. 1998). Association-based bias can therefore have a major effect on quantity estimation. However, there is no indication that it interacts with quantity-based bias to influence people's sensitivity to changes in quantity.

In the context of food quantity estimation, numeric reference points can be provided externally. For example, people may have information about the quantity of other food available at the time of the estimation (such as the number of calories of other dishes on the menu). Even completely irrelevant contextual information, such as the quantity of packages per shipping box, can influence quantity judgments (Wansink et al. 1998). In the absence of an external reference point, people may generate a reference point internally, for example, by using the average or usual quantity of food. Semantic primes can occur in the form of the health positioning adopted by food and restaurant brands, by the type of food available on the menu or in the store, or by specific nutritional claims made (e.g., "low fat"), which are often erroneously extrapolated (Andrews et al. 1998).

--- Insert Figure 1 here ---

Summary

Figure 1 summarizes the key predictions of the framework. In all conditions, estimated food quantity follows an inelastic power function of actual food quantity ($ESTQ = a \times (ACTQ)^b$

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where a > 0 and b < 1. Increasing the salience of food quantity makes estimation less inelastic (i.e., increases b). In contrast, association bias has a main effect (i.e., the intercept a changes) but does not interact with the effects of the actual quantity (b remains constant).

IMPROVING THE ACCURACY OF FOOD QUANTITY ESTIMATIONS

The framework allows us to make predictions about the effectiveness of three common interventions designed to improve the accuracy of food quantity estimation: 1) consumer education and motivation, 2) increasing the salience of the food quantity, and 3) encouraging people to use a piecemeal estimation.

Education and Motivation

Disclosing information about biases and motivating consumers to be more accurate can help reduce the association-based bias caused by numeric anchors or by semantic primes. To be really effective, however, the intervention has to do more than alert people to the existence of the bias; it needs to specifically prompt them to question the validity of the biasing association. For example, Mussweiler, Strack, and Pfeiffer (2000) showed that asking people to give reasons why an anchor is inappropriate reduces association-based bias.

Education and motivation, however, cannot reduce psychophysical biases because the shape of the psychophysical function is driven by automatic low-level perceptual processes (Arkes 1991; Raghubir 2007). Education and motivation can only influence the intercept of the power function, and hence shift the curve up or down in Figure 1, but cannot improve the accuracy with which people notice a change in actual food quantity.

Salience

A straightforward way to improve the accuracy of food estimation is to increase the visual salience of the food quantity itself. In contrast to the educational and motivational strategy, increasing the salience of food quantity can improve how accurately people perceive changes in food quantity because it increases the elasticity of quantity estimation. By influencing both the intercept and exponent of the psychophysical functions, an enhanced salience can improve both the mean food quantity estimate and people's responses to changes in food quantity.

To improve the salience of food in pantries or refrigerators, the visual area or volume taken up by the food must be a good indicator of its actual quantity. This can be done by storing food visibly, by reducing clutter, and by avoiding stacking packages at different depths in the pantry shelves. This can also be done at the single pack level by increasing the correlation between package size and the actual quantity of the contents. For example, multiple packages of food can be spread and put in a visible place in the centre of the pantry. The shape of the package itself can also be simplified so that it does not imply more food than it actually contains (Folkes & Matta 2004). Finally, when packages or portions are supersized or downsized, marketers can increase the salience of the quantity change by changing only one of the dimensions of the package (e.g., its height) rather than by changing all of its dimensions.

Piecemeal Estimation

Compared to the first two remedies, the piecemeal estimation procedure does not attempt to correct the level or the shape of the psychophysical functions but follows Arkes' recommendation to exploit the level or the shape of the existing psychophysical function by

changing the location of the options or the location of one's reference point on the curve. The basic notion is to avoid significantly underestimating a large quantity by dividing it into multiple smaller portions and by asking people to estimate each of these smaller portions. The piecemeal estimation therefore replaces a single estimation of a large quantity located on the flatter portion of the psychophysical curve (e.g., the white circle in Figure 1) which is likely to be significantly underestimated with multiple estimations of smaller quantities located on the steeper portion of the curve where the slope is closer to 1 and the curve is close to the 45° line (e.g., the black squares in Figure 1).

Note that, in addition to increasing the sensitivity to changes in meal size, the piecemeal decomposition strategy also leads to an overall increase in food quantity estimation because it reduces the likelihood of forgetting a component of the meal (Srivastava & Raghubir 2002). It is unclear, however, whether piecemeal estimation can reduce association-based bias. In addition, this procedure is only appropriate for the estimation of large quantities, which tend to be underestimated. Conversely, with very small quantities it is possible that the estimation will exceed the actual amount; using the piecemeal estimation procedure would compound the overestimation error. In this case, people should be encouraged to estimate the amount of food contained in a larger quantity than the one that they are first estimating (e.g., estimate for two packages and divide the estimate by two).

In practice, to estimate a total amount of product inventory, people can first estimate the amount of food contained in one single package and then multiply it by the total number of packages. To estimate the amount of food contained in one meal, people can estimate the quantity of food in the main dish and the side dish and then add them. To estimate the size of

a single food portion (e.g., the number of calories in a sandwich), people can mentally cut the sandwich in four portions and then multiply their estimate by four.

Summary

At least three strategies are available to help people estimate food quantity more accurately. Educating consumers and motivating them to be more accurate is the standard strategy and can help reduce association-based bias by prompting people to question the validity of the associations. However, education and motivation alone cannot improve the elasticity of quantity estimation. In contrast, increasing the visual salience of food quantity can help reduce all types of bias. Adopting a piecemeal estimation procedure can also help reduce quantity-based bias and the underestimation of large quantities. Compared to the salience-based approach, it does not involve actually changing the way the food is packaged or displayed. Unlike the educational approach, it does not require a lot of explaining and can be easily implemented. However, it needs to be reversed for very small quantities and may not reduce association-based bias.

EXPERIMENTAL AND EMPIRICAL EVIDENCE

In this section, I review empirical and experimental research (conducted primarily with Brian Wansink) which tests parts of the framework in three different contexts: 1) when estimating the amount of calories contained in restaurant meals, 2) when estimating the amount of food available in household pantries, and 3) when estimating the size of food portions.

There is a large body of research on how people estimate consumption intake (Livingstone & Black 2003). Although some of their findings, such as the over-reporting of small intakes and the significant under-reporting of large intakes, are consistent with the predictions of the framework, they are not reviewed here because these

studies were not designed to test the predictions of the framework. For the same reason I do not review the studies examining the consequences of food quantity estimation biases (for a recent review, see Krishna 2007).[1]

Restaurant Meal Estimation

In two papers (Chandon & Wansink 2007a; 2007b), Brian Wansink and I examined how people estimate the quantity of calories/food contained in fast-food meals in a series of field and laboratory studies. In the field studies, we asked people who had just finished eating a meal at either Subway (which claims to serve healthy meals) or McDonald's (which does not make that claim) to estimate the total number of calories in the meal. We recorded and confirmed the type and size of the food and drinks from the wrappings left on the tray and obtained information about the actual number of calories in the food and beverage from the restaurant's web site. To increase the comparability of McDonald's and Subway meals, we restricted the analysis to meals consisting of a sandwich, a soft drink, and a side order.

--- Insert Figure 2 here ---

The first panel of Figure 2 shows the mean estimated and actual number of calories for each quartile of the meals ordered at Subway and McDonald's. The predicted power curves fitted the quantity estimations very well for both restaurants, indicating that quantity estimations followed an inelastic power function of actual quantity, as expected. The power exponent was approximately .5 for both restaurants, which meant that meals twice as large only appeared about 41% bigger ($2^{\wedge.5}$) and hence that perceived quantity grew a lot more slowly than actual quantity. As a result, people were roughly accurate for small meals but significantly underestimated the number of calories in the large meals ordered from both Subway and

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[1] Prior research has shown that quantity biases influence consumption incidence and quantity (Folkes & Matta 2004; Raghubir & Krishna 1999; Wansink 1996; Wansink 2004; Wansink & Chandon 2006; Wansink et al. 2007), repurchase timing (Chandon & Wansink 2006), side-dish consumption (Chandon & Wansink 2007a), food waste (Chandon & Wansink 2006), and the stereotyping of obese people (Chandon & Wansink 2007b).

McDonald's. More importantly, although Subway meals tended to be smaller (the median meal contained 504 calories at Subway vs. 891 at McDonald's), calorie estimations were higher for McDonald's meals than for Subway meals of the same size. For example, the mean predicted calorie estimation for a 1,000 calorie meal was 744 calories for McDonald's but only 585 calories for Subway. In summary, the stronger association of Subway with healthy meals led people to believe that Subway meals contained fewer calories than same-calorie McDonald's meals but did not influence how accurately people responded to changes in meal size.

In a laboratory study (Chandon & Wansink 2007b), Brian Wansink and I examined the ability of two remedies to improve the accuracy of fast-food meal size estimation: increased information and motivation, and the piecemeal estimation procedure. Participants were first asked to order the amount of chicken nuggets, fries and beverage that they wanted. Participants in the control condition were simply asked to estimate the total number of calories of the meal that they had ordered. Participants in the bias disclosure condition were informed about the direction and magnitude of quantity-based biases and incentivized to provide accurate estimates. Participants in the piecemeal estimation condition were asked to estimate the number of calories of the nuggets, fries, and beverage separately.

As the bottom panel of Figure 2 shows, the lab study replicated the findings of the field study even in a controlled setting in which the type of food was held constant and only its quantity varied. More importantly, Figure 2B shows that increasing information and motivation led to a general increase in calorie estimation but did not improve people's sensitivity to changes in quantity (the exponent remained unchanged). In contrast, the piecemeal estimation procedure raised the exponent to a value that was not statistically different from one, thereby effectively

removing quantity biases. These results were also replicated in a study of certified dieticians who, although they were generally more accurate than the average consumer, still provided more elastic, and hence more accurate, estimations when asked to evaluate each component of a meal separately. (for details on this study, see Chandon & Wansink 2007b).

Pantry Inventory Estimation

In another paper with Brian Wansink (Chandon & Wansink 2006), we examined people's estimations of the quantity of remaining product inventory by conducting four studies, two in the lab and two in the field. In one study we asked people to examine a picture of a pantry containing eight target products. We manipulated food quantity (1, 3, 7, or 9 units) and the salience (high or low) of these products. Salient products were located on the top or middle shelf of the pantry (as opposed to the bottom shelf), separate from other products (rather than being crowded together with them), and were given multiple facings when available in more than one unit (rather than being stacked together in an overlapping fashion). After evaluating some non-target brands, the pantry picture was removed and participants were asked to estimate the number of units of the eight target products and their home inventory for these products.

--- Insert Figure 3 here ---

Figure 3 shows that, as expected, pantry inventory estimations followed an inelastic power function of the actual product quantity (average power exponent b = .42). Second, estimations of low quantity levels were slightly above the truth whereas estimations of large quantity levels were significantly below the truth. The first panel of Figure 3 also shows that the elasticity was lower when salience was low (b = .32) than when it was high (b = .49). As a

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result, estimations were more accurate when product quantity was salient than when it was not. These findings were replicated in two field studies in which we asked supermarket shoppers to estimate the home inventory of 23 food products, to rate the visibility of these products in their pantries, and to then check the actual home inventory levels. These studies also showed that the least elastic—and thus least accurate—estimations were those of product categories often bought on impulse and difficult to stockpile.

To test the biasing effects of anchors, we categorized participants into a low and high internal anchor groups based on their average home inventory level for each product. The second panel of Figure 3 shows that quantity estimations were higher among participants with a high (vs. low) home inventory but that the power exponent remained unchanged. This shows that, as predicted by the framework, association-based bias has a main effect on quantity estimations but does not interact with quantity effects. Similar reference effects were found in another study which showed that providing high and low external anchors by asking people whether the quantity was above or below 9 or 1 shifted quantity estimations but did not change the power exponent.

Food Portion Estimations

With Nailya Ordabayeva (Chandon & Ordabayeva in press), we studied people's estimations of the quantity of product contained in packages or portions that either increased in all three spatial dimensions (height, weight, length) or in only one dimension (e.g., height only). In the first two studies we asked people to estimate the weight of six sizes of the same product that either grew along one spatial dimension (e.g., strands of wool with increasing length) or along three spatial dimensions (e.g., spherical balls of wool of increasing diameter). Participants were given the weight of the smallest size and were supposed to realize that each increasing

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size contained twice as much product. Although we did not use food products in these studies, three other studies show that the effects of dimensionality apply equally well to food and non-food products.

--- Insert Figure 4 here ---

As Figure 4 shows, quantity estimations were highly inelastic in the 3D condition (b = .68) and almost perfectly elastic in the 1D condition (b = .93). For example, an eight-fold increase in product quantity gave the appearance of being a four-fold increase in the 3D condition, and a seven-fold increase in the 1D condition. This study therefore provided additional evidence of the quantity-based bias predicted by the framework. It also showed that, as expected, increasing the salience of the product quantity change (by increasing the physical size of the product along one dimension only) improved the accuracy of people's estimations. These findings were replicated in a quantity production task (as opposed to a quantity estimation task) in which participants had to pour predetermined quantities of product into or out of cylindrical glasses (in which volume changes in 1D) or conical glasses (e.g., martini cocktail glasses, in which volume changes in 3D). Again, changes in quantity appeared smaller in the 3D condition. When participants were asked to triple an existing volume of alcohol, they poured roughly the right amount into cylindrical glasses, but almost four times the amount into the conical glasses.

In two papers, Brian Wansink and I studied the effect of association-based bias on portion size estimation by examining the effects of specific nutritional claims such as "low-fat" (Wansink & Chandon 2006) and the health claims of the food brand (Chandon & Wansink 2007a). In one study, we showed a ham sandwich and manipulated the health claim by

changing the name of the restaurant ("Good Karma Healthy Foods" vs. "Jim's Hearty Sandwiches") and the other items on the menu. In the control condition, we asked participants to estimate the number of calories of the target food. To test the effectiveness of providing debiasing instructions, participants in the "consider the opposite" condition were first asked to find arguments supporting the idea that the ham sandwich was a generic meal that was not typical of the restaurant that served it. Figure 5A shows that in the control condition calorie estimations were significantly lower for the healthy menu than for the unhealthy menu. Conversely, in the "consider the opposite" condition calorie estimations were essentially the same regardless of the health associations. Prompting people to question the validity of health primes therefore eliminated association-based bias.

--- Insert Figure 5 here ---

In (Wansink & Chandon 2006), we examined the effects of association-based bias on food quantity estimation, and also on actual food consumption. We gave people who were going to watch a movie a bag of granola that was either labeled "regular" or as "low fat". In order to test the debiasing effect of providing information about the actual quantity of product, half the bags were labeled "Contains one serving", whereas the other half did not have any serving size information. At the end of the movie, we asked people to estimate how much granola they had eaten and we weighed what was left in their bags to measure how much they had actually eaten. As Figure 5B shows, "low fat" labels led to underestimation in all conditions. When serving size information was absent, calorie estimations were similar in both conditions, even though calorie intake was higher by 51% in the "low-fat" condition. When serving size information was present, "low-fat" labels actually reduced calorie estimation despite increasing calorie intake by 12%. Overall, these studies provide additional evidence

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that health associations bias quantity estimation and that encouraging people to question their validity can reduce this type of associative bias, but that simply providing serving size information is not enough.

CONCLUSION

In the battle against overeating, the current emphasis on what to eat has obscured the importance of quantitative decisions about how much to eat. This chapter builds a framework of how people estimate food quantity, what should be done to improve their accuracy, and what we know about how people estimate the quantity of food in restaurant meals, pantry inventory, and portion sizes. Table 1 summarizes the key findings.

--- Insert Table 1 here ---

There still are, of course, a number of important unresolved issues about the process through which people estimate food quantities. With the exception of those studies in which quantity was estimated post intake, all the studies reviewed here focused on visual estimation. Future research should examine how people integrate different sensory modalities. For example, Krishna (2006) showed that sensory modality (touch vs. vision) influences judgments of the size of cylindrical glasses. It would also be interesting to examine individual differences. For example, Krishna, Zhou, and Zhang (2008) found that individuals with independent (vs. interdependent) self-construals are more prone to spatial judgment biases. Finally, it would be interesting to conduct a systematic analysis of the differences between experienced, remembered, and predicted quantity estimations. This would allow us to study the dynamics of quantity estimation and hence to examine why so little learning seems to occur over time.

TABLE 1

KEY FINDINGS ON FOOD QUANTITY ESTIMATION BIASES AND REMEDIES

Findings	References
Biases in how people estimate food quantities	
Food quantity estimations are inelastic to actual quantity changes (i.e., they change more slowly than they should). As a result, people accurately estimate small food quantities but strongly underestimate large quantities.	(Chandon & Ordabayeva in press; Chandon & Wansink 2006; Chandon & Wansink 2007b; Krider et al. 2001)
Estimations are more elastic when a) the secondary spatial dimension of the product is perceptually salient, b) the visual area in the pantry is correlated with actual quantity, or c) packages or portions increase along only one spatial dimension.	(Chandon & Ordabayeva in press; Chandon & Wansink 2006; Krider et al. 2001)
Health associations created by a) branding, b) nutrition labels or c) reference points bias quantity estimations but do not influence people's sensitivity to changes in quantity.	(Chandon & Wansink 2007a; Chandon & Wansink 2006; Wansink & Chandon 2006)
How to improve the accuracy of food quantity estimations	
Providing information about the existence of biases and incentives can shift estimations but does not reduce association-based bias unless consumers are specifically asked to question the validity of the health claim	(Chandon & Wansink 2007a; Chandon & Wansink 2007b).
Increasing the salience of food quantity by making it more visible in the pantry, or by only supersizing packages and portions along one dimension, improves both the mean accuracy of estimation and sensitivity to quantity changes.	(Chandon & Ordabayeva in press; Chandon & Wansink 2006; Krider et al. 2001)
Piecemeal estimation procedure improves sensitivity to quantity changes and reduces the underestimation of large quantities, but is only appropriate for large quantities and does not reduce association-based bias.	(Chandon & Wansink 2006; Chandon & Wansink 2007b).

FIGURE 1

PREDITED EFFECTS OF SIZE, SALIENCE, AND ASSOCIATION-BASED
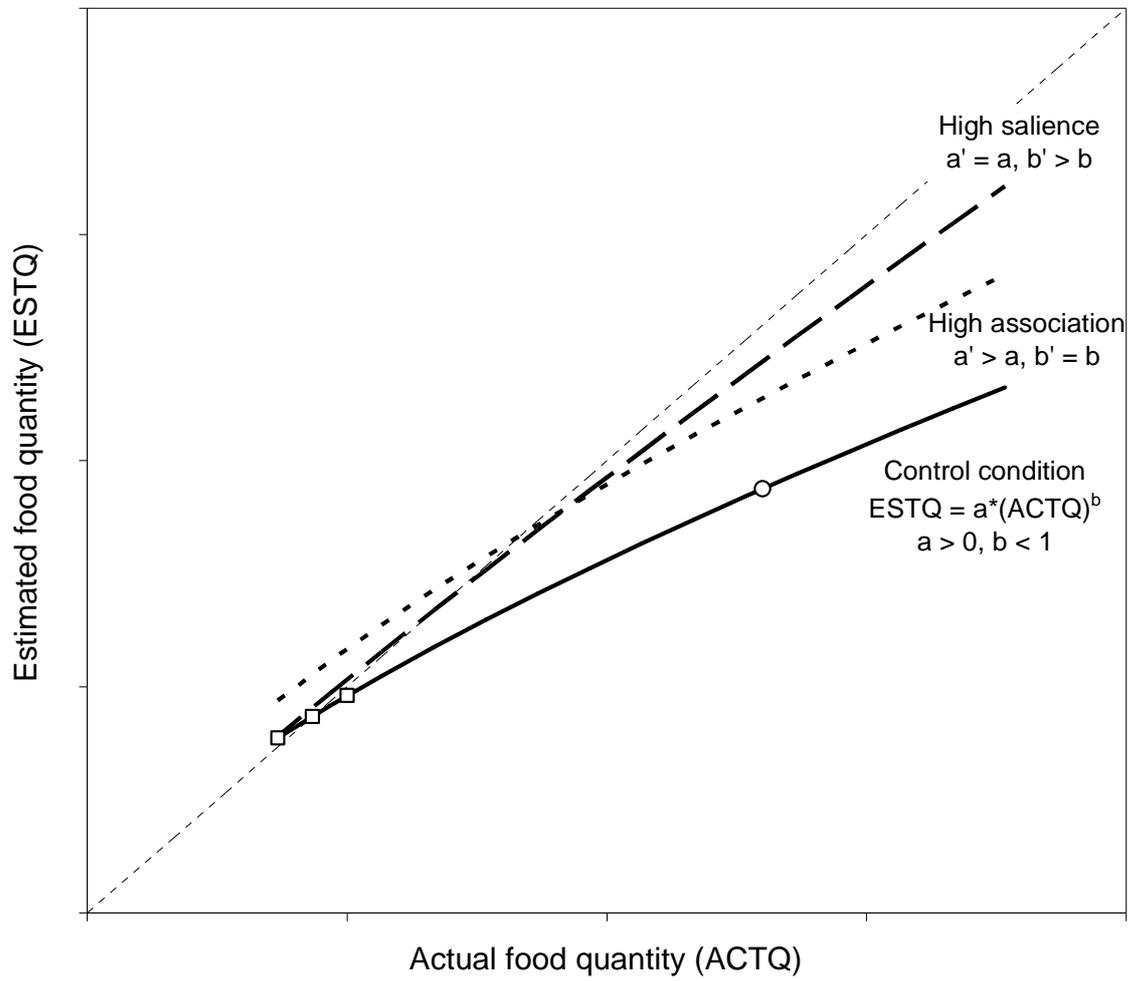BIASES ON FOOD QUANTITY ESTIMATIONS

FIGURE 2

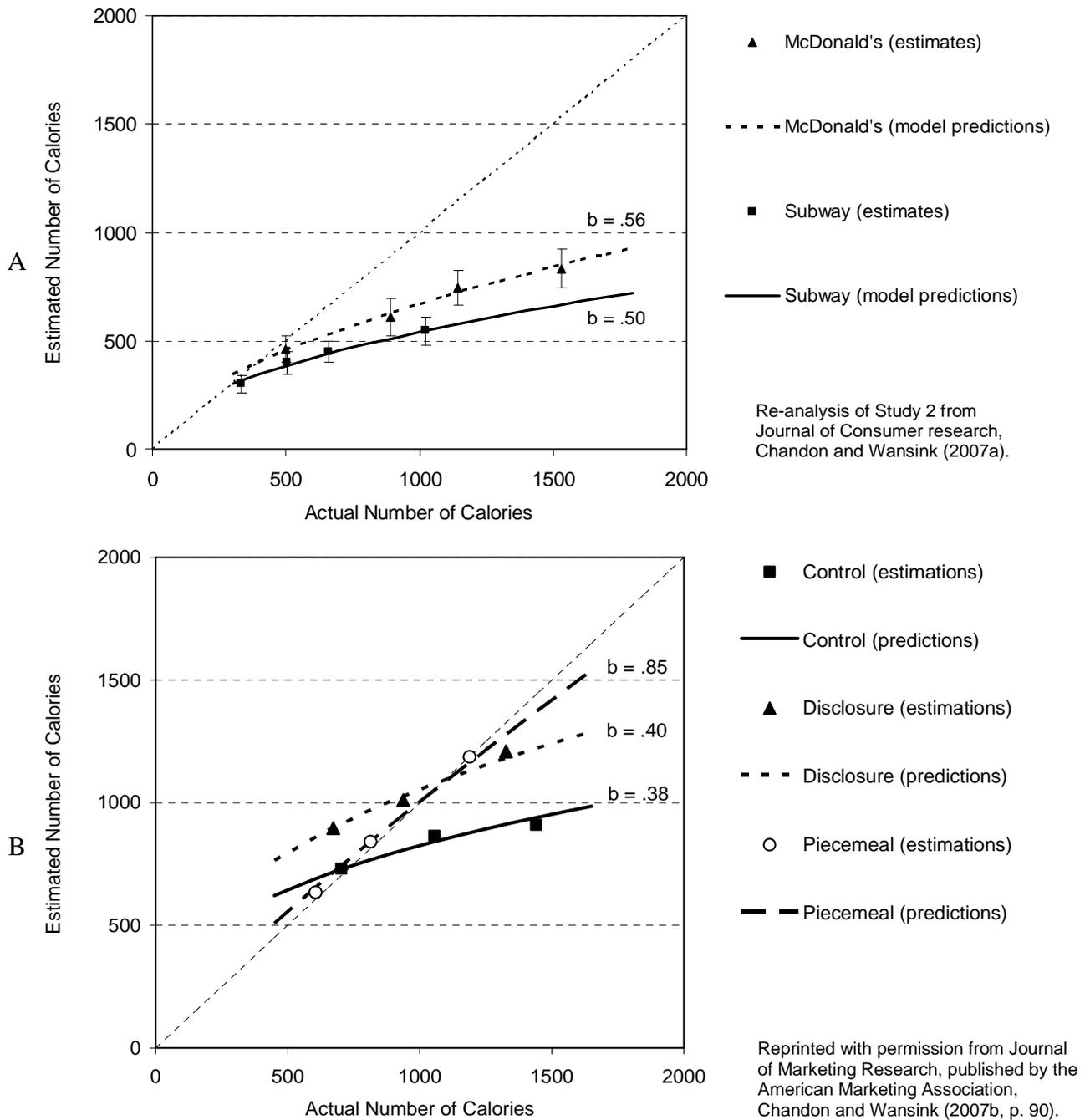RESTAURANT MEAL ESTIMATIONS: EFFECTS OF HEALTH CLAIMS (A)
AND OF TWO REMEDIES (B)

FIGURE 3

PANTRY INVENTORY ESTIMATIONS: EFFECTS OF QUANTITY AND SALIENCE (A)
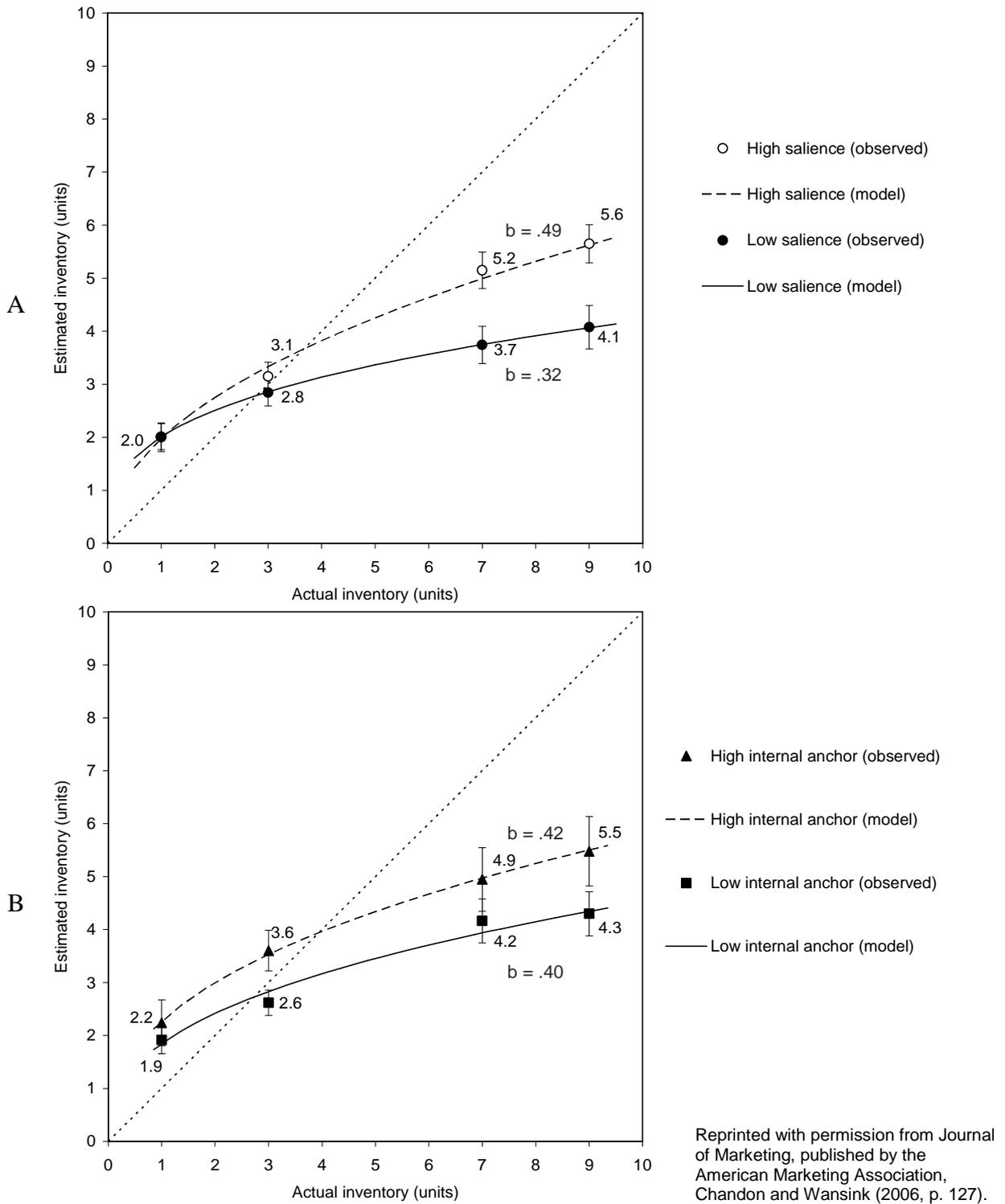AND OF INTERNAL ANCHORS (B)

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FIGURE 4

PORTION AND PACKAGE ESTIMATIONS: EFFECTS OF THE SPATIAL
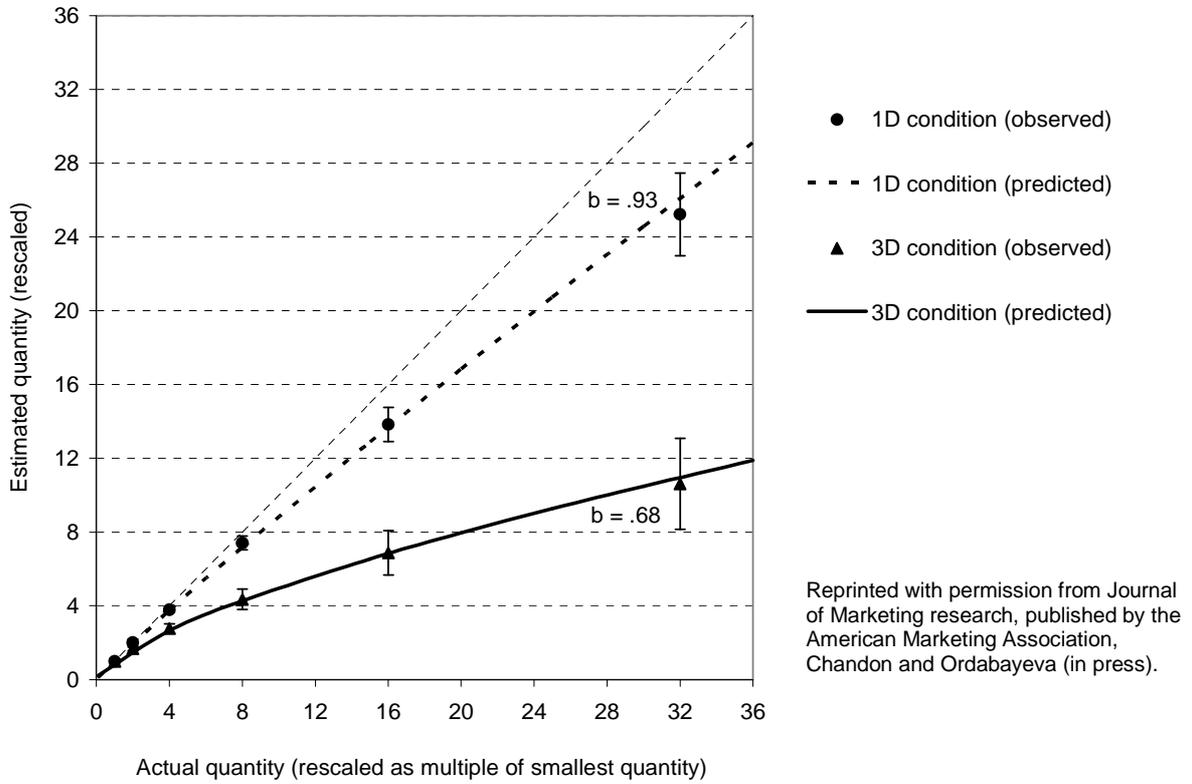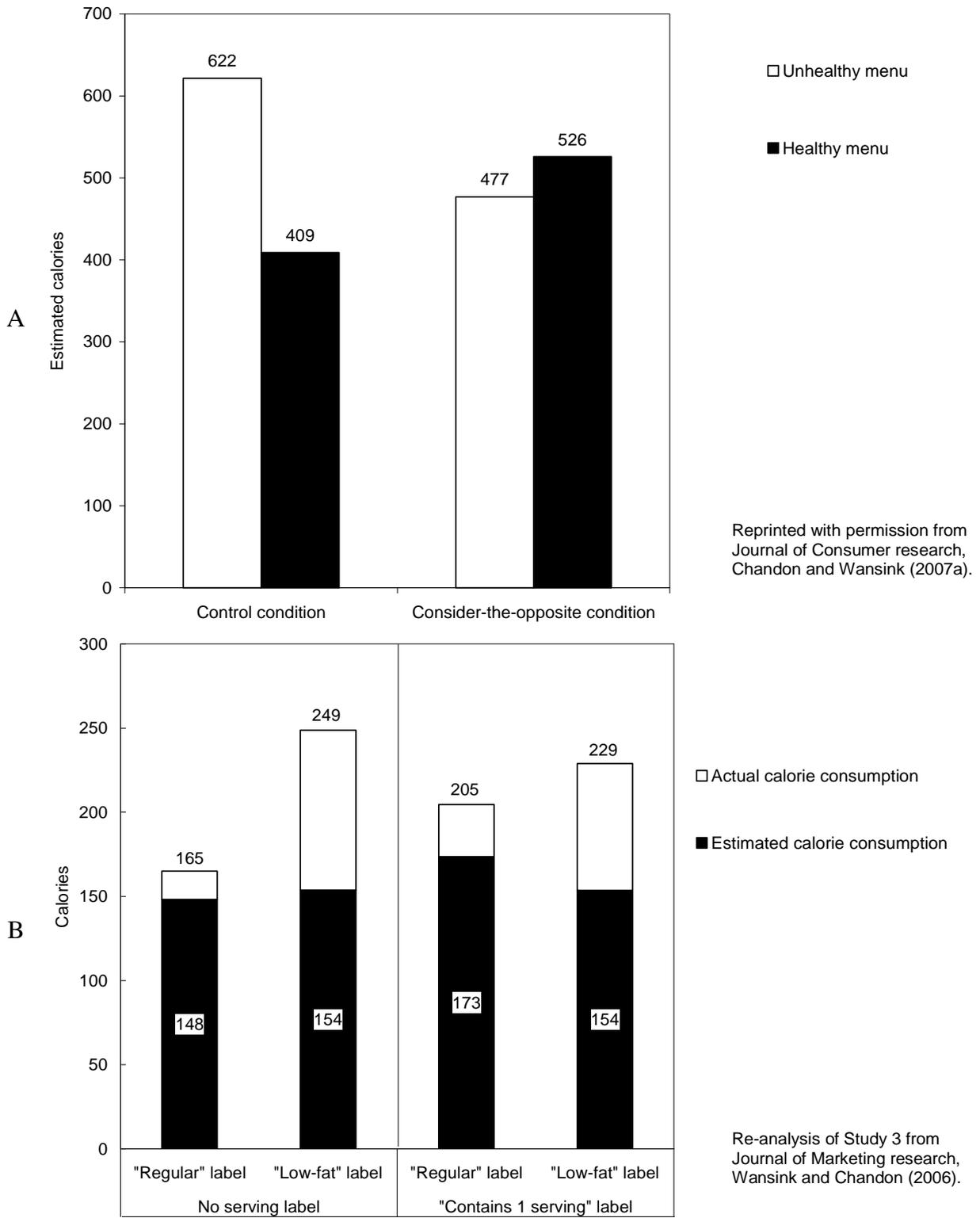DIMENSIONALITY OF PRODUCT SIZE CHANGE

Reprinted with permission from Journal of Marketing research, published by the American Marketing Association, Chandon and Ordabayeva (in press).

FIGURE 5

PORTIONS ESTIMATIONS: EFFECTS OF HEALTH CLAIMS AND REMEDIES ON
ESTIMATIONS (A) AND ON ESTIMATIONS AND ACTUAL CONSUMPTION (B)

Reprinted with permission from
Journal of Consumer research,
Chandon and Wansink (2007a).

Re-analysis of Study 3 from
Journal of Marketing research,
Wansink and Chandon (2006).

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