

Research Report

## Visual illusion in mass estimation of cut food

Yuji Wada, Daisuke Tsuzuki, Naoki Kobayashi, Fumiyo Hayakawa, Kaoru Kohyama\*

*National Food Research Institute, 2-1-12, Kannondai, Tsukuba, Ibaraki 305-8642, Japan*

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### Abstract

We investigated the effect of the appearance of cut food on visual mass estimation. In this experiment, we manipulated the shape (e.g., a block, fine strips, or small cubes) of food samples of various masses, and presented them on a CRT display as stimuli. Eleven subjects participated in tasks to choose the picture of the food sample which they felt indicated a target mass. We used raw carrots and *surimi* (ground fish) gel as hard and soft samples, respectively. The results clearly confirm an existence of an illusion, and this indicates that the appearance of food interferes with visual mass estimation. Specifically, participants often overestimated the mass of finely cut food, especially fine strips, whereas they could accurately estimate the mass of block samples, regardless of the physical characteristics of the foods. The overestimation of the mass of cut food increased with the food's actual mass, and was particularly obvious with increases of apparent volume when cut into fine strips. These results suggest that the apparent volume of a food sample effects the visual estimation of its mass. Hence we can conclude that there are illusions associated with the visual presentation of food that may influence various food impressions, including satisfaction and eating behaviour.

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### Introduction

Food processing not only changes the flavour and texture of food, but also its visual appearance. One reason why we elaborate food appearance, for example dressing up a dish, or being mindful of colorfulness, might be our implicit knowledge of the great influence that the appearance of food has on our eating behaviour and appetite.

A number of studies have clearly shown that various aspects of food appearance, such as colour, shape, and display, are important factors that affect various aspects of human eating behaviour (e.g., Dunker, 1939; Kanig, 1955; Rolls, Rowe, & Rolls, 1982). It has been reported that visual appearance affects taste and flavour perception (Calvo, Salvador, & Fisman, 2001; DuBose, Cardello, & Maller, 1980; Gottfried & Dolan, 2003; Pangborn, 1960; Richardson-Harman & Booth, 2006; Zellner & Kautz, 1990). Visual volume, height, and how food is dressed up are important factors which influence perceptions of mass,

satisfaction, and appetite (Hsee, 1998; Ichikawa, Seki, Wang, & Higgins, 2006).

In addition, there is a case in which the apparent volume of food has a correlation with the amount of mastication. Kohyama, Nakayama, Yamaguchi, Yamaguchi, Hayakawa, and Sasaki (2007) quantified the mastication effort for finely cut foods while subjects ate mouthfuls of raw carrot, *surimi* (ground fish) gel, and so on. For raw carrots, the number of chews, masticatory time, and total muscle activity evaluated by electromyography were greater for finely cut samples than for block samples of the same mass. Cut samples with similar apparent volumes, but of lower mass were often eaten with less mastication effort until swallowing than were block samples. In other words, the apparent volume of food might correlate with the mastication effort in raw carrot. For *surimi* gel, cutting did not change the mastication effort. They concluded that cutting food does not help to reduce mastication effort in spite of the general belief that finely cut food should be easy to eat.

A possible explanation for such a discrepancy between our belief and actual mastication is the tight relationship between the perception of mass or weight and that of size.

\*Corresponding author. Tel.: +81 29 838 8031; fax: +81 29 838 7996.  
E-mail address: [kaoruk@affrc.go.jp](mailto:kaoruk@affrc.go.jp) (K. Kohyama).

A size–weight illusion known as the Charpentier’s illusion, under which the perceived weight of an object depends not only on its physical weight, but also on its size (Charpentier, 1891) is a good example. The illusion is strongest when subjects grasp the objects so as to obtain haptic cues about size, but is still powerful when only visual information about size is available, as when lifting objects by strings in order to eliminate tactile size information (Ellis & Lederman, 1993). The mechanisms underlying the illusion remain a matter of controversy. Leading hypotheses include visual or haptic expectations or high-level cognitive processes of weight or mass, while a few researchers assert that the illusion is primarily a haptic phenomenon (Amazeen & Turvey, 1996). One hypothesis is that the illusion stems from a mismatch between the expected and the actual sensory feedback related to weight: the visual overestimation of weight for a large object is accompanied by a greater lifting force, compared to what would be applied to a smaller object, applied to it by the observer, which results in a faster lifting movement and a lighter estimated weight (Masin & Crestoni, 1988; Ross, 1969). Recent studies have suggested that the size–weight illusion can be caused by high-level cognitive and perceptual factors that are independent of errors in sensorimotor prediction (Ellis & Lederman, 1998; Flanagan & Belzner, 2000). These studies demonstrate that human perceptions of weight are tied to perceptions of size or volume. Kohyama et al. (2007) pointed out that cut food with the same volume has a lower mass than a block. Hence, finely cut food, which appears to have a greater volume than a block of food, might lead to the overestimation of the mass of the food when our estimation of mass depends on the visual volume. It is plausible that this is the same as the overestimation of weight or mass by visual size, which occurs in the size–weight illusion. We may feel as though we have eaten a greater mass of cut food than what we actually have. The difference between size–weight illusion and visual mass expectation of food is in the behaviour of the observer. In the former, an observer hefts an object and perceives its weight, while in the latter, the observer assesses the object’s weight without hefting it. However, there have not been many scientific studies that have examined the relationship between visual food volume and mass estimation.

The aim of this study is to investigate how visual aspects of cut food influence visual mass estimation by using experimental methods in order to develop ways to use the visual presentation of food to manipulate the eater’s perception by applying the size effect on visual mass estimation. To do this, we conducted two experimental sessions to examine whether the visual size–mass illusion of food would occur as a function of actual mass and visual volume accompanied by changes of shape. Subjects participated in an experiment based on a method of magnitude production, in which they were asked to identify a stimulus displaying a target mass (Gescheider, 1997; Stevens, 1957, 1958). We used raw carrots and *surimi* gel as

hard and soft samples, respectively, to examine whether the physical characteristics of food influenced the subjects’ visual mass estimation of the samples.

## Methods

The experiment included two separate sessions, which were different only in the visual stimuli observed by participants. In one experimental session, we manipulated the shape of raw carrot samples (a block, fine strips about 5 mm × 1 mm × 1 mm, and small cubes about 3 mm × 3 mm × 3 mm) into various masses, and presented them on a CRT display. Raw carrot, which exhibits high fracture stress and a small deformation (Kohyama et al., 2007), was used as a representative of hard food. Participants were asked to choose the picture of the sample of food with a target mass as magnitude production. In the other session, *surimi* gel, which exhibits low fracture stress and a large deformation (Kohyama et al., 2007), was used as a soft sample.

## Participants

There were 11 participants, eight females and three males ranging in age from 26 to 43 years, in both experimental sessions. All of them had normal or corrected to normal visual acuity. All participants had had, in their daily lives, the experience of eating raw carrot and *surimi* gel, and were familiar with their textures.

Their cooking experience ranged from 0.5 to 20 years, but no one was, or had been, a professional cook or chef (Table 1). Written informed consent was obtained after a complete explanation of the study. The study was approved by the institutional ethics committee.

## Apparatus and stimuli

We used a personal computer (Dell Precision 380) with a 22 in monitor (Iiyama HM204DA) to present pictures of

Table 1  
The cooking profile of subjects

No.	Sex	Age	Number of cooking days/week	Cooking frequency/day	Cooking experience (years)	Number of family members
1	F	27	7	2	8.0	1
2	M	32	3	1	5.0	2
3	M	30	7	1	8.0	1
4	F	26	7	2	0.5	2
5	F	38	7	2	1.5	1
6	F	28	7	2	8.0	2
7	F	43	7	2	20.0	1
8	F	37	7	2	12.0	2
9	F	37	7	2	15.0	2
10	F	27	2	2	2.0	1
11	M	29	4	1	7.0	1

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