


SDNPA 2017  
Saturday, June 10, 11:30-12:45  
Man or Machine?





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## Digital wire mesh portion estimation from food images: validity and reliability

Tom Baranowski, PhD  
Professor of Pediatrics, Baylor College of Medicine  
Editor-in-Chief, *Games for Health Journal*  
Editor-in-Chief, *Childhood Obesity*

### A technology based alternative: eButton

- Mingui Sun, PhD, Wenyan Jia, PhD & team developed this at the University of Pittsburgh
- Multisensor unit (camera, accelerometer, light sensor, GPS? extensive memory)
- Images at 4 sec intervals (10,800/12 hrs)
  - Analysis of images



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Our role in this technology development

- Provide a “real world” test with children

This presentation focuses on portion size estimation

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### Prior Research: Validation of child 24hr by observation at school (4<sup>th</sup> & 5<sup>th</sup> graders)

- Recall done next morning

### Errors in 24hr with children

- Intrusions (@35% of foods)
- Omissions (@15% of foods)
- Errors increase as time since intake increases
- 50% error is **unacceptable!**






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### eButton dietary assessment process


- Takes images at 4 sec intervals throughout day (10,800/12 hrs)
- Images encrypted upon taking
- Images uploaded at end of day (by parent)
- Images unencrypted following morning
- Food images identified (others deleted)
- Foods identified (where possible) (dietitians)
- Portion sizes estimated (wire mesh or visual procedure)
- Interview with child (& parent) end of 2<sup>nd</sup> day
- Food record completed to reflect all information collected

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### Portion Size Estimation

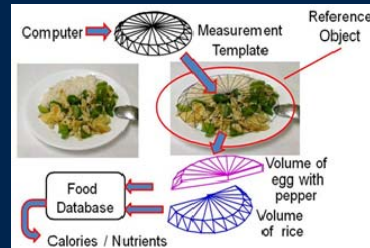
- Identify plate size
- Select most appropriate wire mesh
- Envelop food image
- Read amount



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## Sliding-finger and mesh software for portion size measurement



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## Study 4 Methods (1)

- 75 foods of diverse shapes
  - In "served" and "left" sizes
  - all measured and plated by a dietitian
- 2 experienced dietitians
- 3 engineers who helped create the wire mesh procedure

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## Outcome Expectations

- High reliability and validity for "served"
  - Dietitians and engineers
- Lower for "left"
  - Since small and irregular shapes
- Lower reliability and validity for "intake"
  - Since it combines errors from "served" and "left"
- Validity slightly lower than reliability
  - Previous study 2.8% error under best of circumstances

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## Study 4 Research Questions

- What is the intercoder reliability and validity when using the wire mesh method for portion size estimation?
- Does this differ for dietitians vs. engineers, by plate/bowl?

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Table 1. Foods selected for portion size validations with different dishes and wire frames

| Food                                  | Dishes                        | Wire Meshes Used  |
|---------------------------------------|-------------------------------|---|
| 1. Scrambled Egg                      | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 2. Long Grain Brown Rice              | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 3. Old Fashion Oatmeal                | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 4. Whole Kernel Corn                  | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 5. Organic Romaine Lettuce            | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 6. No Salt Added Black Beans - Canned | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 7. Fruit Cocktail - Canned            | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 8. Mashed Sweet Potatoes              | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 9. Frozen Broccoli                    | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 10. Campbell's Vegetable Soup         | Large Bowl, Small Bowl        | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |
| 11. HERB Half and Half Iced Tea       | Glass, Plastic Cup            | Cylinder  |
| 12. Apple                             | Plate, Small Bowl             | Before picture: Half Ellipse, Half Sphere, Section of Sphere, Sphere<br>After picture: Half Ellipse, Half Sphere, Section of Sphere |
| 13. Cheese Cake                       | Plate                         | Wedge, Half Ellipse   |
| 14. Orange                            | Plate, Small Bowl             | Before picture: Half Ellipse, Sphere<br>After picture: Half Ellipse, Section of Sphere  |
| 15. Pizza Slice                       | Plate                         | Wedge, Half Ellipse   |
| 16. Cake                              | Plate                         | Cuboid, Half Ellipse, Cylinder  |
| 17. Kraft Macaroni and Cheese Spirals | Plate, Large Bowl, Small Bowl | Half Ellipse, Half Sphere, Cylinder, Section of Sphere  |

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Table 2. Wire frame library for portion size volume estimation.

| Wire Frame Model  | Appearance | Examples                          |
|-------------------|------------|-----------------------------------|
| Cuboid            |            | Chocolate, Cake                   |
| Cylinder          |            | Drinks, liquid in bowls           |
| Sphere            |            | Apple, orange                     |
| Wedge             |            | Pizza, Pie, Cake                  |
| Ellipse           |            | Drinks                            |
| Half sphere       |            | Half orange face down             |
| Half ellipse      |            | Blends of food (apple, etc. more) |
| Half sphere       |            | Half peach face up, lemons        |
| Section of sphere |            | Blends of food                    |
| Tunnel            |            | Cup, cereal                       |
| Irregular shape   |            | Steak, chicken                    |

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Table 3. Reliability coefficients for different portion variables across different raters and the true value

| Variables     | Images (n) | Inter-rater Reliability ICC Values (for two dietitians) | Validity ICC Values (for two dietitians + true value) | Inter-rater Reliability ICC Values (for three engineers) | Validity ICC Values (for three engineers + true value) |
|---------------|------------|---|---|--|--|
| Volume served | 75         | 0.771   | 0.766   | 0.820  | 0.815  |
| Volume left   | 75         | 0.629   | 0.596   | 0.847  | 0.832  |
| Intake volume | 75         | 0.590   | 0.677   | 0.755  | 0.745  |

Note: Intake is calculated as the difference between the initial "serving" and what is "left" on the plate, but if the estimated volume of the leftover is larger than the served, the intake is set to 0.

Legend: ICC – intraclass correlation

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## Possible solutions

- Through training with feedback
- Some technological fixes needed
  - More wire mesh shapes
  - More easily manipulated
- Need to fit square plates
- More work needed
  - Bill & Melissa Gates Foundation grant

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## THANK YOU!

Dank u wel! (Dutch)

Děkuji! (Czech)

DANKE! (German)

MUITO OBRIGADO! (Portuguese)

M GO!! (Chinese, Cantonese)

ARIGATŌ! (Japanese)

MERCI BEAUCOUP! (French)

MUCHAS GRACIAS! (Spanish)

SERDECZNIE DZIĘKUJĘ! (Polish)

SHUKRAN! (Arabic, Middle East)

TACK SAMYCKET! (Swedish)

THAK! (Mangyan)

EPCHARISTOI! (Greek)

Xie Xie! (Chinese, Mandarin)

Khaw Khun mai! (Thai)

Grazie! (Italian)

teşekkür ederim (Turkish)

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## Problems with images

- Plate/bowl not fully in image
- Mesh did not always tightly fit
- Food shape irregular (especially "left")
- Size of plate misspecified
- "density" not in FNDDS for some foods

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## Collaborators

- Alicia Beltran, MS (Dietitian, Project Manager)
- Hafza Dadabhoy, MS, RD (Dietitian)
- Courtney Ryan, MS (Dietitian)
- Ruchita Dholakia, MS (Statistician)
- Janice Baranowski, MPH, RD (Co-I, Dietitian)
- U Pittsburgh
  - Wenyan Jia, PhD (Electrical Engineer)
  - Mingui Sun, PhD (Electrical Engineer)

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Table 4. Intraclass correlation coefficients for different serving containers.

|  | for two dietitians |                   |              | for three engineers |                   |              |
|--|--------------------|-------------------|--------------|---------------------|-------------------|--------------|
|  | Small Bowl (n=48)  | Large Bowl (n=42) | Plate (n=56) | Small Bowl (n=48)   | Large Bowl (n=42) | Plate (n=56) |
| Volume (served and left images combined) | 0.669              | 0.712             | 0.833        | 0.820               | 0.844             | 0.966        |

Note: The total number of images in this analysis is 146. Four "glass" images were excluded since the same was too small to reliably estimate the intraclass correlation. Since separating the images into serving container type categories resulted in a small number of images per category, the served and left images were combined for these analyses alone.

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Table 5. Statistics of relative errors for all ratings and for each dietitian separately

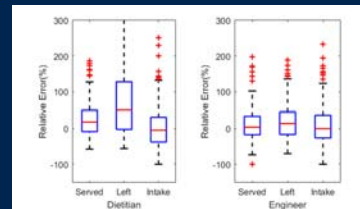
| Measure            | Served    |           |        | Left      |           |        | Intake    |           |        |
|--------------------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|
|                    | Images(n) | Median(%) | IQR(%) | Images(n) | Median(%) | IQR(%) | Images(n) | Median(%) | IQR(%) |
| for all Dietitians | 150       | 17.9      | 58.7   | 150       | 50.7      | 130.2  | 148       | -4.6      | 69.2   |
| for all Engineers  | 225       | 3.7       | 51.4   | 225       | 14.1      | 62.3   | 222       | -0.03     | 63.2   |

Legend: RE: relative error = (observed - true)/true \*100; IQR: Interquartile range: also called the midspread or middle 50%, equals to the difference between 75th and 25th percentiles

## Notes:

1. \*Since the real food intake in one image is zero, the REs from two dietitians and three engineers for this food has to be eliminated.
2. The median values of relative error: Intake < served < left
3. Big estimation variance can be seen in IQR, especially for left food. Probably due to the small size of the leftover.
4. Median values (served and left) for dietitians are positive and larger than the estimates from engineers. It may be caused by the fitting procedure if outer perimeter is used. But fortunately, when calculating the volume of intake, such bias can be cancelled to some extent.
5. Overestimation can be seen in all of these conditions.

**Figure 1:** Box-and-whisker plot of REs for the two dietitians and three engineers. On each box, the central line represents the median of the relative errors over all the food samples. The bottom and top edges of the box are respectively the first and third quartiles, which is the interquartile range (IQR). The extreme regions (with a greater distance from the median than 1.5 times the IQR) are the ends of the lines extending from the IQR. Points outside this region are plotted individually as asterisks, representing potential outliers.

Table 6. Percentage of estimates within  $\pm 10\%$  of true volume

| Measure            | Served       | Left         | Intake       |
|--------------------|--------------|--------------|--------------|
| for all Dietitians | 27/150=18.0% | 18/150=12.0% | 22/150=14.7% |
| for all Engineers  | 45/225=20.0% | 34/225=15.1% | 38/225=16.9% |

## List of steps and duration for processing images for one day

| Steps  | Duration      |
|--|---------------|
| 1. Download pictures via big file (unzipping/extracting)   | 15-20 min     |
| 2. Decryption of uploaded pictures   | 45-50 min     |
| 3. Selection of pictures related to food events using windows viewer   | 2-3 hr        |
| 4. Blurring pictures and de-identifying personal information, faces, etc.: Only on pictures needed for food identification | 30-45 min     |
| 5. Entering food items with pictures in Software   | 1 hr          |
| 6. Food verification recall using NDSR and Food Amount Booklet   | 45 min - 1 hr |
| 7. Editing food names and portions of any items after verification   | 45 min- 1 hr  |
| 8. Volume estimation for foods that apply using the software   | 1-1.5 hr      |
| 9. Quality assurance   | 1 hr          |
| *Time varies depending on the amount of pictures and the amount of foods.  |               |